APPENDIX D

ELECTRIC BAG TRACTOR BTE-06: DATA ANALYSIS REPORT

SPECIFIC CHARGE AND DISCHARGE DATA FROM THE ON-BOARD DATA COLLECTION SYSTEM INSTALLED ON TRACTOR BTE-06

DATA ANALYSIS

TIME PERIOD OF DATA COLLECTED

Data collection began on April 16 at 7:07 am and ended on June 27 at 9:00 pm. Data was sampled at the rate of one (1) sample every two (2) seconds (0.5Hz).

FILES DOWNLOADED

During this 78-day period, data files were automatically saved into the on-board computer once each eight hours.[1] Approximately once a week the files were downloaded and transmitted to eTec for reduction and analysis. Files were DAQSTANDARD formatted files; using the DAQSTANDARD software, each file was converted into an Excel format. The three data files for each day were then merged into a single file in order to obtain one 24 – hour data file. Each file contained the following information:

- date stamp
- time stamp
- cell voltages for 24 cells
- bi-directional battery current
- battery temperature

Date and time stamp on each file was used to create daily files with charge/discharge data. Time stamps along with a sampling rate of 1 sample each two seconds was used to graph voltages, currents, or temperatures for that the day. Sampling rate and current column was used to calculate the battery pack capacity. Cell voltage data were used to monitor the behavior of individual cells and variations in total battery pack voltage during the charge/discharge cycles.

GRAPHICAL REPRESENTATION OF TYPICAL ONE DAY DATA

Sampling rate of 1 sample per 2 seconds provided each 24 hours data file with an Excel file with over 43,000 rows of data. This large number of datum made it impossible to graph an entire 24 hours period of data in a single graph.

To provide a proper perspective on the data collected, a typical day of operation was selected. The day selected was Wednesday, May 23, 2001. This day was representative of the normal operation and service requirements for all of the electric bag tractors utilized during this project. A typical 12 hours of data are presented in Figures 1 through 4.

Figure 1 shows that in the morning of May 23, 2001, there were 3 drive cycles (indicated by the negative current values). Following these drive cycles, the vehicle was placed on charge. Following the charge cycle the vehicle completed a number of drive cycles (>15).

[1] During the data collection period, the five days of data collected from May 24 and May 28 were inadvertently overwritten by project personnel while changing out the data collection media. While this loss of data was unfortunate, there was no apparent skewing of results. Tables 4 and 5 reflect the lost data by showing blank lines for those dates.

The duration's of these drive cycles can be measured in minutes. The corresponding variations in battery pack voltage are shown in Figure 2.

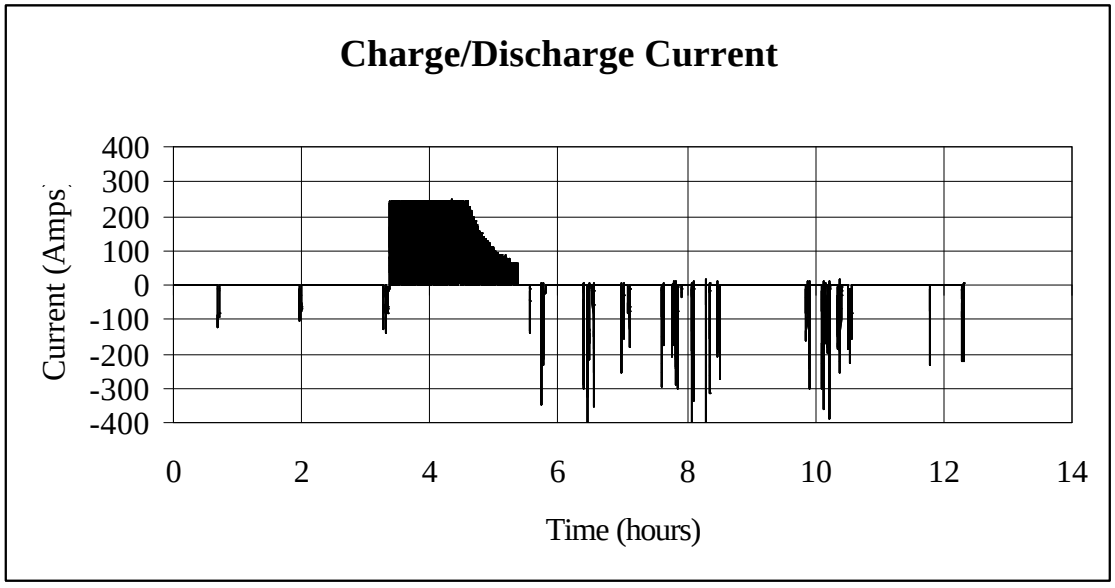


Figure 1. Drive cycle and charge currents recorded on May 23, 2001

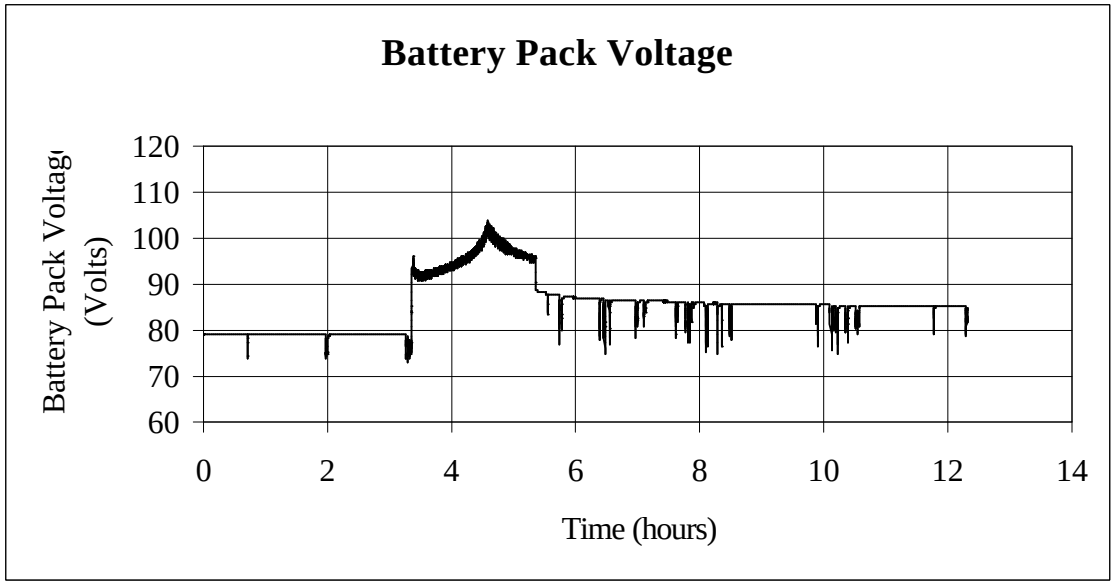


Figure 2. Battery pack voltage recorded on May 23, 2001

During the charge cycle the battery pack voltage increased from about 80V to over 100V. After the vehicle was taken off charge and placed back into service, battery pack voltage immediately decreased, and then gradually dropped as the number of drive cycles increased.

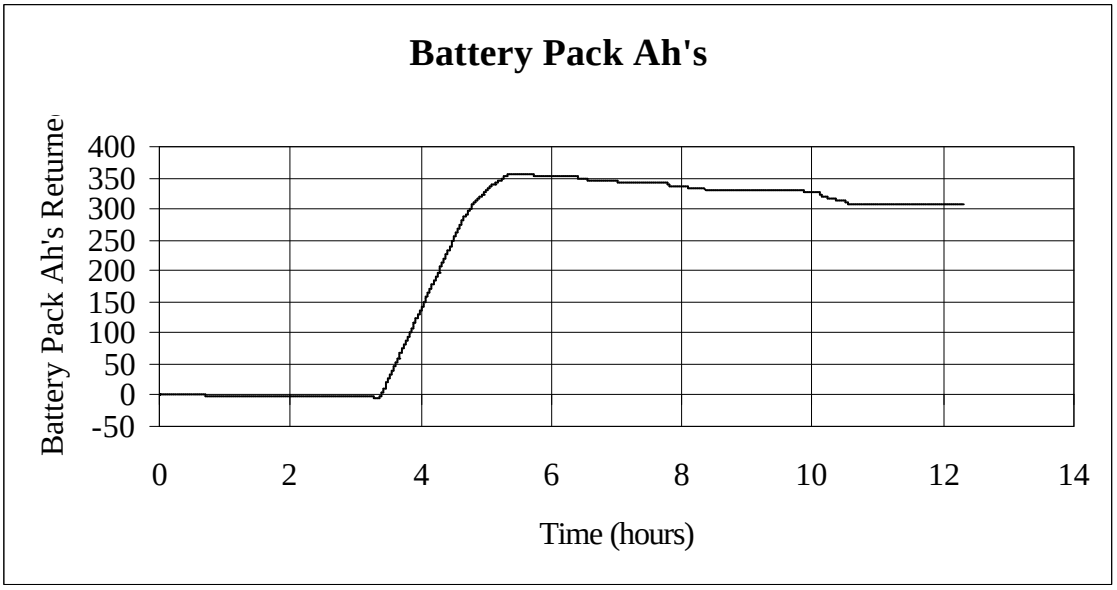


Figure 3. Battery pack Ah's recorded on May 23, 2001

Figure 3 shows that in about two hours of charging, ~ 360 Ah of energy were returned to the battery. With each ensuing drive cycle, the energy returned was consumed. By the end of May 23, about 50 Ah of battery energy was consumed used.

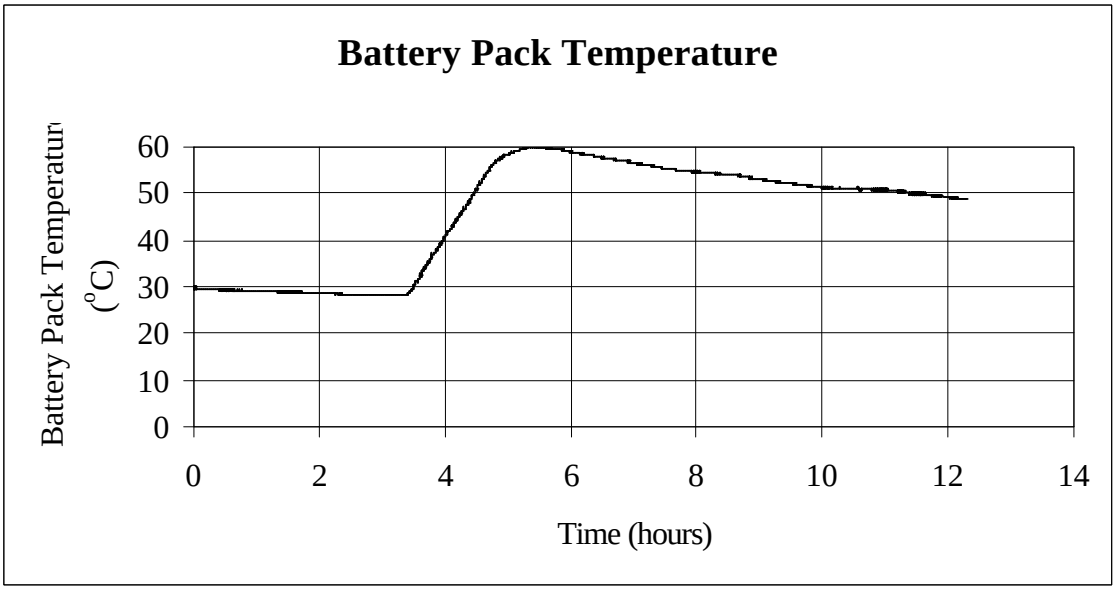


Figure 4. Battery pack temperature recorded on May 23, 2001

Figure 4 shows that battery temperature increased during the charge cycle. The high rise in temperature was due to placement of the thermocouple. To ensure the temperature rise

of the most limiting component was captured, the thermocouple was installed adjacent to an inter-cell bus bar.[2]

Calculated Parameters For One Day's Data

The following parameters were calculated from data collected for May 23, 2001:

- Number of drive cycles,
- Duration of each drive cycle in minutes,
- Ampere-hours used during each drive cycle,
- Average current during each drive cycle in Amps,
- Maximum current during each drive cycle in Amps,
- Standard deviation of current during each drive cycle in Amps,
- Average time between two drive cycles in minutes,
- Number of charge cycles,
- Duration of each charge cycle in minutes,
- Ampere-hours restored into the battery pack during the charge cycle,
- Average charge current in Amps during the charge cycle,
- Maximum charge current in Amps during the charge cycle,

[2] Although the battery manufacturer (Exide) would not provide information on the most limiting component(s),during commissioning tests eTec concluded that the intercell busbars were the most limiting component under sustained high current conditions. Other manufacturer's had previously provided eTec with information that during conditions of sustained high current, the intercell busbar was usually the most limiting component. Since full charge current values were set at the maximum sustained values allowed by Exide (240A), the use of the intercell busbar as the most limiting component was consistent with that information.

Calculated discharge cycle data from the file for May 23, 2001 are presented in Table 1.

TABLE 1

No	Duration	Capacity	I^3_{max}	I^2_{avg}	St. Dev
	min	Ah	Amps	Amps	Amps
1	0.37	0.29	124.00	47.91	44.64
2	1.30	1.44	104.00	66.44	21.95
3	4.77	3.70	136.00	46.57	28.82
4	0.47	0.41	141.00	52.71	49.34
5	3.13	3.48	346.00	66.72	75.90
6	2.87	4.44	404.00	92.92	95.51
7	3.60	3.92	256.00	65.36	50.10
8	1.63	1.28	291.00	47.04	70.82
9	17.57	8.92	406.00	30.46	63.42
10	1.23	2.02	405.00	98.11	113.50
11	2.20	2.19	275.00	59.74	62.11
12	2.90	1.28	302.00	26.44	52.62
13	5.77	10.36	388.00	107.83	68.82
14	3.23	4.51	252.00	83.75	52.43
15	3.80	4.88	218.00	77.00	42.68
16	0.30	0.23	234.00	46.33	75.12
17	1.37	1.11	220.00	48.83	60.15

Table 2 shows the summary of Drive Cycle information calculated using data from May 23, 2001.

TABLE 2

Drive Cycles		
Total Number of Drives Cycles	-	17
Average Duration of Drive Cycle	min	3.32
Average Ah's used per Drive Cycle	Ah	3.20
Average Maximum Drive Cycle Current	Amps	264.82
Average Drive Cycle Current	Amps	62.60
Average Drive Cycle Current Standard Deviation	A	60.47
Total Drive Time	min	56.50

[3] Sample rate was 0.5Hz

Table 3 shows the summary of Charge Cycle information calculated using data from May 23, 2001

TABLE 3

Charge Cycles		
Total Number of Charge Cycles	-	1
Total Charge Time	min	121.60
Ampere-hours in	Ah	360.40[1]
Average Charge Current	Amps	246.60
Initial Battery Pack Voltage	V	80.83
Final Battery Pack Voltage	V	96.09
Voltage Increase	V	15.26
Initial Battery Pack Temperature	^{o}C	28.30
Final Battery Pack Temperature	^{o}C	60.20
Battery Pack Temperature Increase	^{o}C	31.90
Average Time Between Driving Cycles	min	74.23

Criteria For Identifying Drive (Discharge) Cycle

To determine the use patterns of the bag tractors, it was necessary to establish certain Criteria. These were stated in the following questions:

- What constitutes a Drive Cycle?
- How will the duration of the Drive Cycle be determined?
- How will the number of Drive Cycles be determined?

Figure 1 shows that a drive cycle duration is normally short. The start and the end of the drive cycle is determined based on the discharge current value. The beginning of a Drive Cycle was ascertained to coincide with battery current becoming negative. The end of drive cycle occurred when the battery current dropped to zero. The time between those two events was stipulated to be a Drive Cycle.

The more difficult task was to determine the number of drive cycles within a single day. In order to determine this, it was necessary to establish the end of each of the Drive Cycles relative to the beginning of the next discharge sequence. [Otherwise stated, how much wait-time needed to pass before the next drive cycle began.] After reviewing all the data and observing Ramp Operations, it was decided that five (5) minutes would be the threshold. Wait times less than five minutes would be considered the same drive cycle; wait times greater than five minutes would establish a new drive cycle.

CHARGE DATA SUMMARY

During the period between April 14 and June 27 there were 32 charge cycles recorded. Table 4 shows the summary of charge data.

TABLE 4

	Date	Charge Time	Average Current	Capacity In	Vinitial	Vfinal	Vinitial - Vfinal	TInitial	Tfinal	TInitial - Tfinal
		min	Amps	Ah	Volts	Volts	Volts	°C	°C	°C
1	23-Apr	33.93	243.70	98.50	80.63	94.25	13.62	17.20	26.90	9.70
2	25-Apr	21.37	222.60	71.20	77.89	90.47	12.58	24.10	41.20	17.10
3	30-Apr	146.30	224.50	436.20	78.70	94.90	16.20	19.60	58.10	38.50
4	4-May	18.43	244.00	63.90	85.84	96.60	10.76	26.30	29.90	3.60
5	6-May	149.70	158.00	394.00	79.65	93.90	14.25	27.30	62.10	34.80
6	8-May	55.70	202.00	185.64	82.51	94.22	11.71	33.90	52.00	18.10
7	10-May	167.80	103.90	291.58	86.03	99.01	12.98	30.80	55.10	24.30
8	11-May	49.17	212.00	172.80	82.77	96.39	13.62	38.60	54.70	16.10
9	11-May	66.40	189.00	209.18	82.10	99.14	17.04	43.50	61.10	17.60
10	13-May	25.63	205.37	87.43	83.30	100.05	16.75	31.20	39.00	7.80
11	14-May	129.47	136.20	293.35	81.57	94.93	13.36	28.50	55.00	26.50
12	15-May	136.93	105.80	240.92	82.03	97.36	15.33	33.30	53.90	20.60
13	18-May	136.27	169.40	334.81	82.60	95.27	12.67	29.10	58.80	29.70
14	23-May	121.60	246.60	360.40	80.83	96.09	15.26	28.30	60.20	31.90
15	30-May	181.47	17.87	54.06	86.83	98.43	11.60	60.90	62.00	1.10
16	30-May	271.87	87.47	396.34	80.75	98.14	17.39	33.60	65.40	31.80
17	1-Jun	275.50	82.20	378.79	82.06	99.28	17.22	33.90	59.90	26.00
18	3-Jun	264.17	76.54	336.98	82.47	99.67	17.20	32.00	59.00	27.00
19	5-Jun	79.47	179.46	237.59	82.30	100.18	17.88	30.20	52.30	23.00
20	7-Jun	83.43	194.65	254.45	82.07	97.32	15.25	36.70	61.30	24.60
21	8-Jun	55.10	223.10	204.84	82.89	101.86	18.97	40.90	58.80	17.90
22	9-Jun	90.37	189.80	285.93	80.96	97.48	16.52	38.00	82.50	24.50
23	11-Jun	83.47	191.52	266.42	81.52	97.12	15.60	30.60	55.50	24.90
24	12-Jun	48.17	174.60	140.17	83.11	99.76	16.65	33.30	46.80	13.50
25	14-Jun	21.63	133.36	48.09	84.64	100.82	16.18	27.60	32.10	4.50
26	14-Jun	66.33	181.52	200.68	82.86	98.77	15.91	35.00	53.10	18.10
27	16-Jun	77.30	190.13	244.96	81.28	93.22	11.94	34.70	57.80	23.10
28	18-Jun	113.63	189.03	358.00	79.96	95.94	15.98	36.00	67.60	31.60
29	20-Jun	254.63	81.76	346.98	84.36	98.14	13.78	40.90	69.70	28.80
30	22-Jun	219.23	109.23	399.13	80.94	98.45	17.53	33.20	61.40	28.20
31	24-Jun	267.93	75.87	338.82	82.13	100.02	17.88	28.90	53.70	24.80
32	27-Jun	153.13	143.80	367.01	80.23	98.39	18.15	23.20	57.40	34.20

Table 4 shows that Ampere-hours returned during the observed period was a minimum of 48.09 Ah and maximum of 436.20 Ah. Figure 5 presents the variation of energy returned to the battery pack capacity during this period.

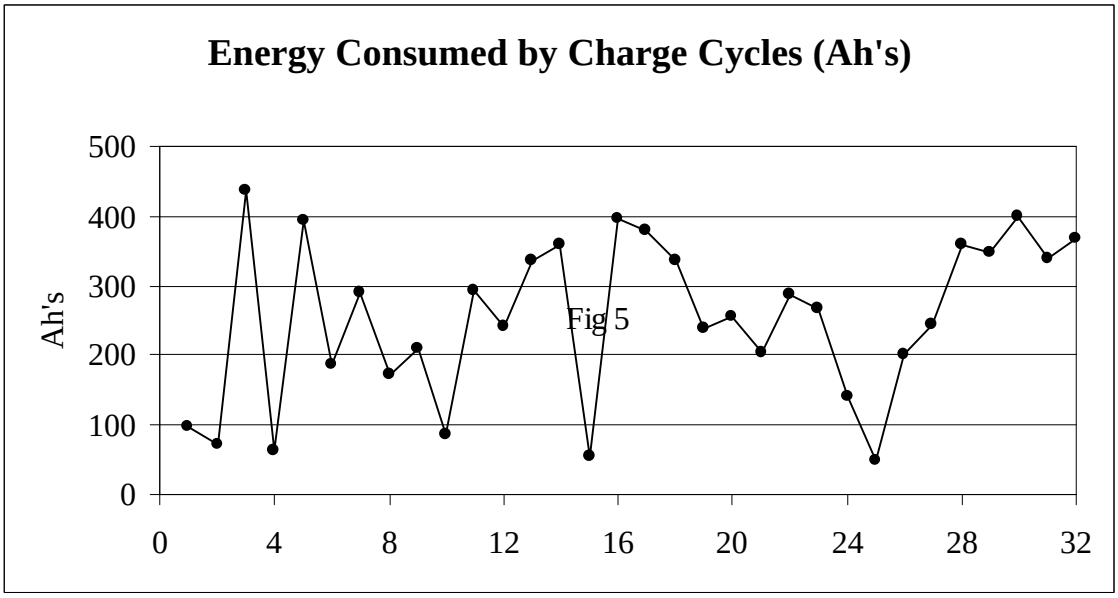


Figure 5. Variation of Recharged Capacity and Charge Cycles

When a trend line is applied it shows that energy returned during the Project's Duration increased at the rate of ~4.25 Ah per charge cycle. The Trend Line is shown in Figure 6.

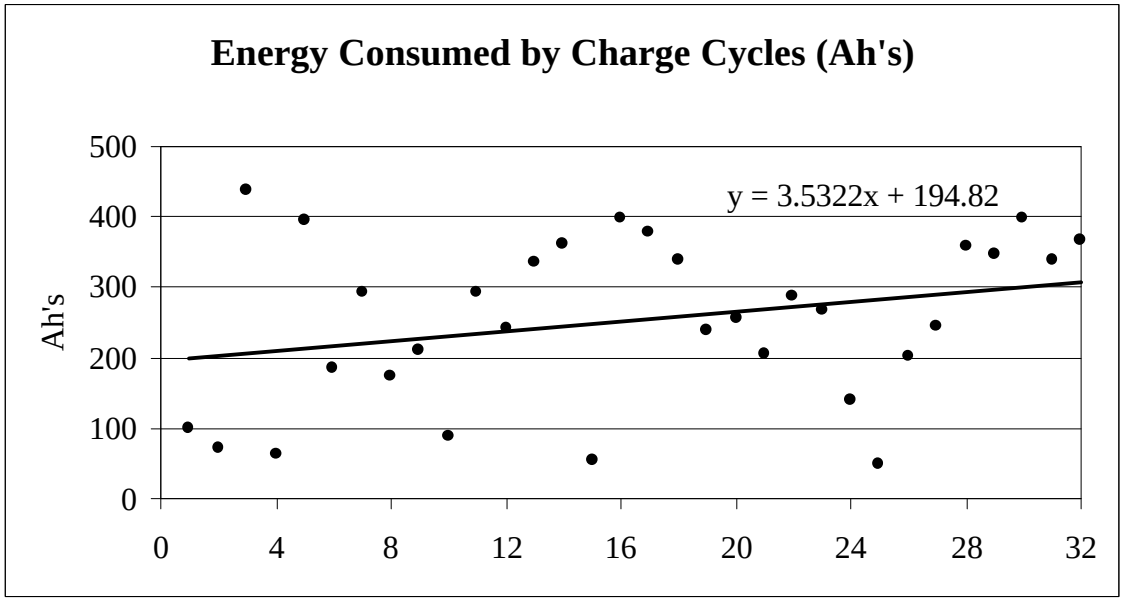


Figure 6. Trend Line for Recharge Capacity

A Histogram for energy returned was developed and is shown in Figure 7. This Figure shows that most of the time energy returned was between 220 Ah and 400 Ah. On one occasion the energy returned was ~ 440 Ah and several times it was less then 220 Ah.

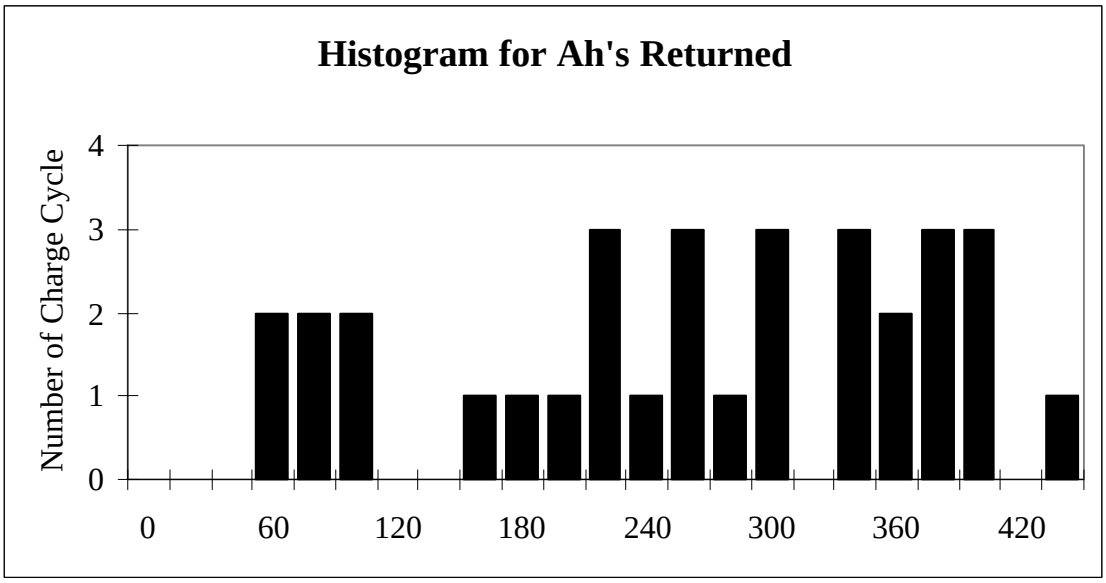


Figure 7. Histogram for Recharge Capacity

Table 4 shows that recharge time during the observed period was a minimum of 18.43 minutes and maximum of 271.87 minutes. Figure 8 shows the variations in recharge times during the sampling period.

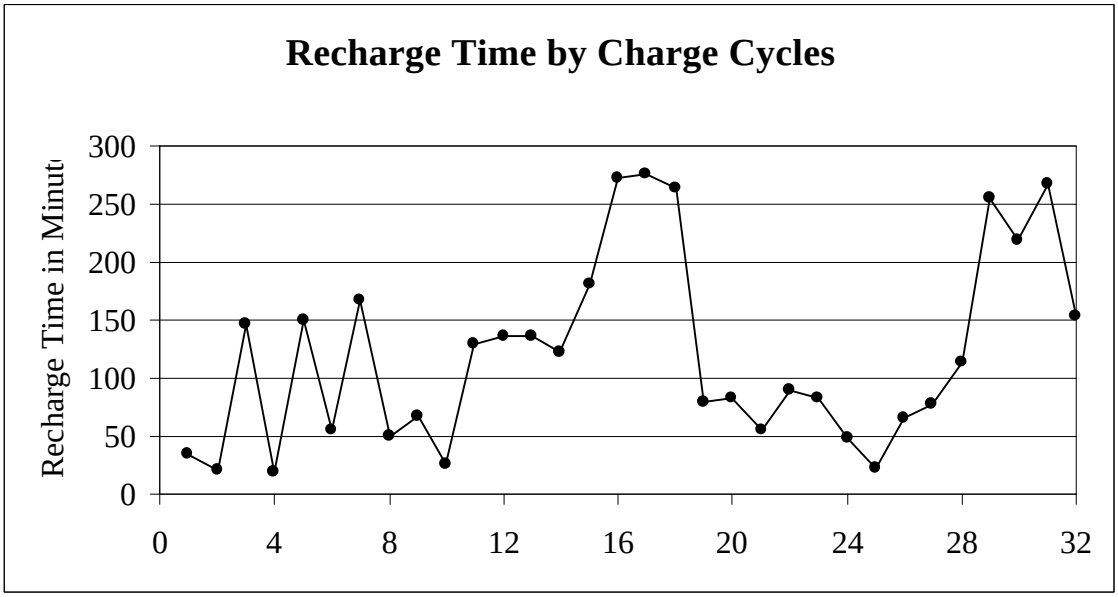


Figure 8. Variation of Recharge Time and Charge Cycles

When a trend line is applied, it indicates that during the sampling period recharge times increased at the rate of ~ 3.44 minutes per charge cycle. See Figure 9.

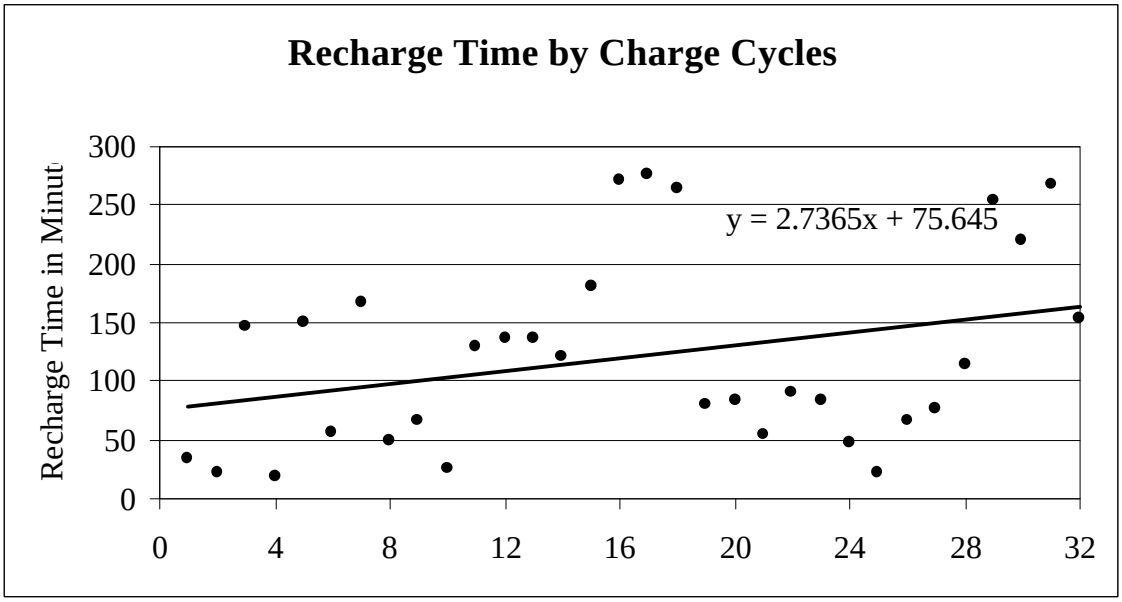


Figure 9. Trend Line for Recharge Time

A Histogram for recharge times shows that the typical recharge time was between 50 and 150 minutes, with most charges less than 110 minutes. See Figure 10.

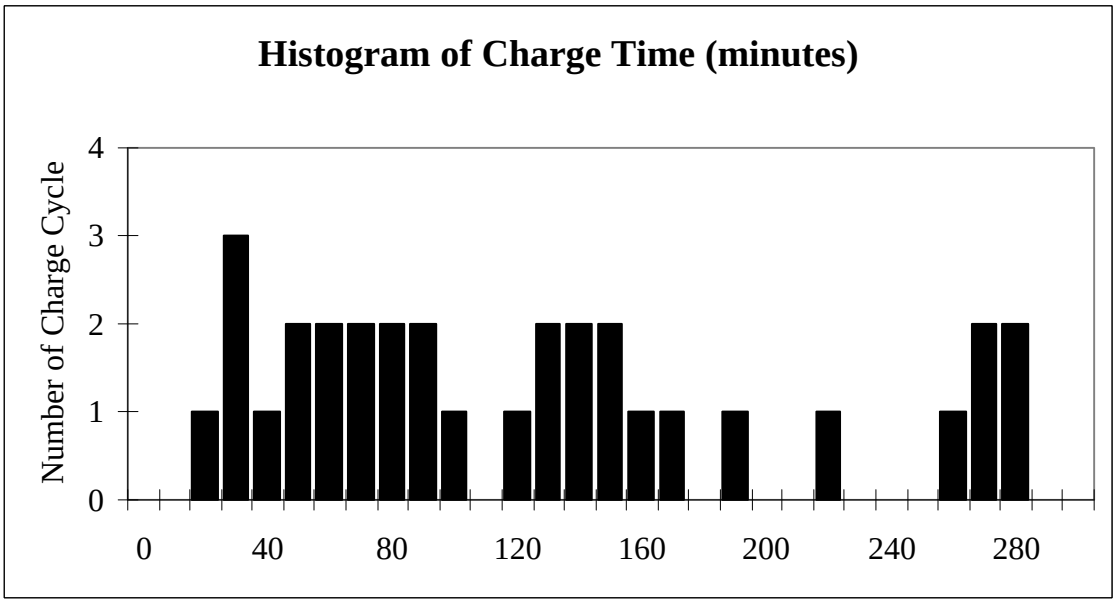


Figure 10. Histogram for Recharge Time

Histograms for recharge current and pre-charge battery pack voltage[4] are given in Figures 11 and 12. Figure 11 shows recharge current. Figure 12 shows the pre-charge battery voltage.

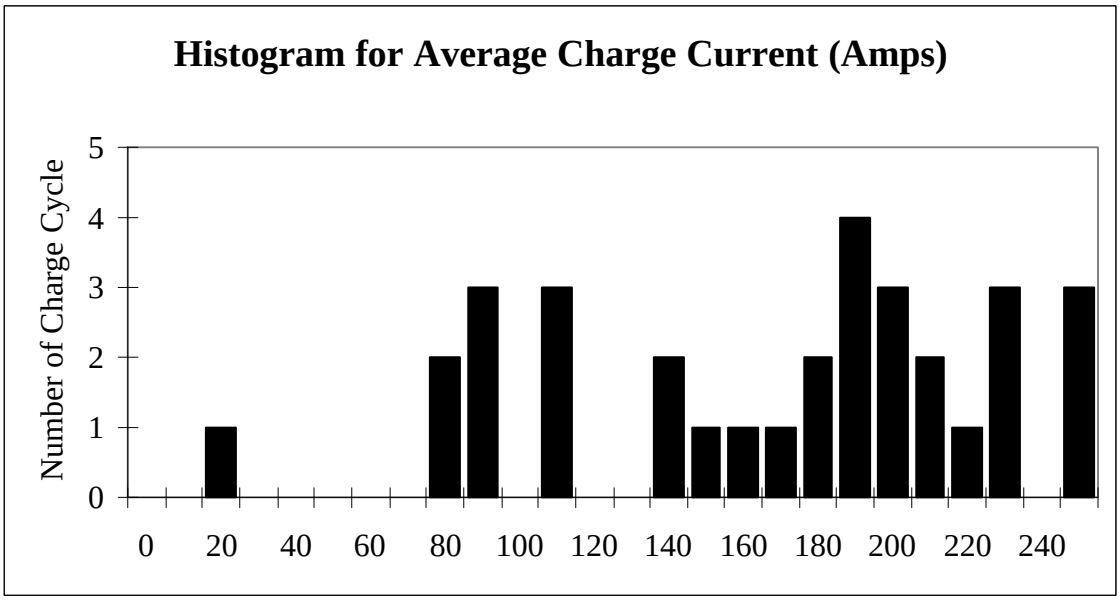


Figure 11. Histogram for Recharge Current

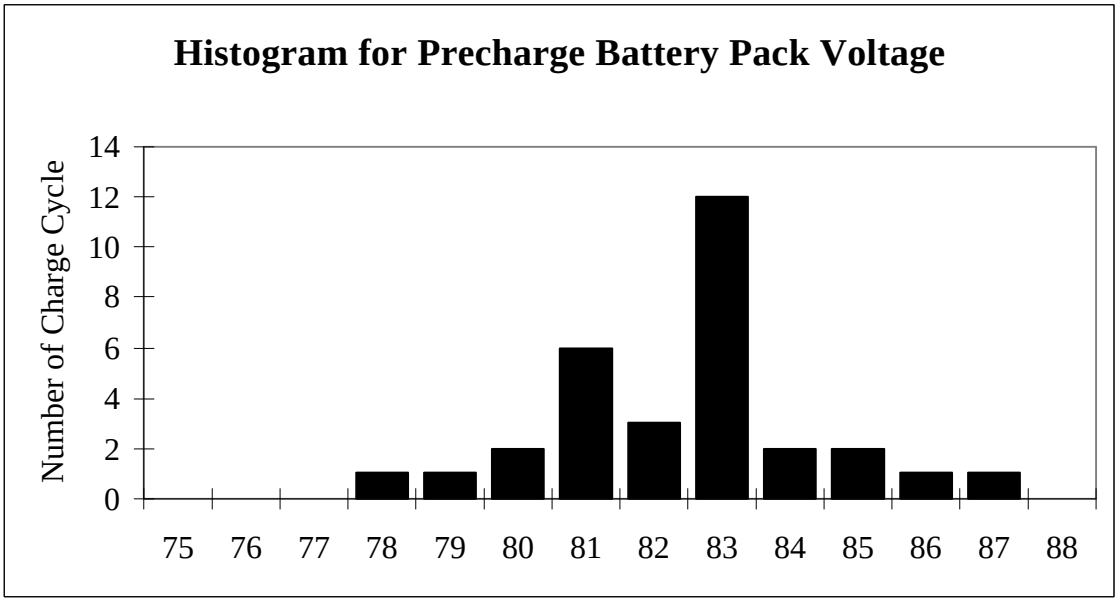


Figure 12. Histogram for Pre-charge Battery Pack Voltage

[4] Pre-charge battery pack voltage is the battery voltage seen by the charger immediately prior to the commencement of charging current flow.

DISCHARGE SUMMARY DATA

During the observed period there was large number of drive cycles every day. For each day the average data were calculated. Blank rows indicate no data were collected that day. These data are presented in Table 5.

TABLE 5

	Cycles	Duration	Ah	Between	Imax	Iavg
		min	Ah	min	Amps	Amps
14-Apr	1	1.23	0.45	1438.77	92.60	21.23
15-Apr	2	1.40	2.17	718.60	366.00	88.77
16-Apr	45	2.73	3.89	29.27	324.51	84.98
17-Apr	24	3.14	3.25	56.86	267.33	62.29
18-Apr	5	3.49	5.00	284.51	228.80	84.12
19-Apr						
20-Apr	6	3.69	3.62	236.31	190.33	55.58
21-Apr	20	2.18	1.97	69.82	144.40	60.57
22-Apr	8	8.84	2.66	171.16	127.00	37.69
23-Apr	3	2.14	2.50	466.78	222.67	49.43
24-Apr	3	3.31	3.23	474.49	184.60	51.30
25-Apr	6	2.13	2.34	234.31	168.17	44.44
26-Apr	1	0.93	0.57	1439.07	148.00	36.64
27-Apr	14	3.03	3.09	99.83	166.43	64.55
28-Apr	13	2.18	1.58	108.59	116.31	43.93
29-Apr	13	2.28	1.33	108.49	90.85	34.23
30-Apr	6	1.94	2.28	213.67	155.00	47.35
1-May	2	6.40	9.29	713.60	336.50	86.69
2-May	28	3.80	4.11	47.63	342.00	69.74
3-May	4	2.37	4.21	357.63	244.50	79.69
4-May	25	3.13	4.07	53.73	321.52	82.93
5-May	23	5.03	4.69	57.36	198.91	60.48
6-May	15	5.42	7.27	80.60	324.73	77.87
7-May	23	4.05	4.51	58.56	305.48	68.99
8-May	22	3.46	3.02	59.47	307.36	81.14
9-May	31	3.85	4.56	42.61	322.71	79.48
10-May	41	3.69	3.68	27.43	329.70	63.81
11-May	41	5.83	6.32	26.47	333.88	68.40
12-May	31	3.63	4.44	42.82	311.77	83.60
13-May	37	4.98	5.31	33.25	342.16	93.58

	Cycles	Duration	Ah	Between	Imax	Iavg
		min	Ah	min	Amps	Amps
14-May	16	3.46	3.56	73.63	312.88	75.39
15-May	36	3.51	4.65	32.69	318.92	87.39
16-May	25	3.27	4.81	54.33	357.00	99.83
17-May	27	7.22	7.17	46.11	245.41	64.51
18-May	12	4.10	3.41	104.55	326.75	63.71
19-May						
20-May	30	3.47	4.06	44.53	329.00	77.16
21-May	12	3.49	4.55	116.51	314.92	93.67
22-May	37	3.73	3.22	35.19	182.49	64.57
23-May	17	3.32	3.20	74.23	264.82	62.60
24-May						
25-May						
26-May						
27-May						
28-May						
29-May	21	4.21	5.53	64.36	294.24	85.37
30-May	22	3.04	2.52	50.06	232.73	63.83
31-May	34	3.26	3.80	39.09	316.24	75.10
1-Jun	37	6.34	5.67	25.44	293.46	75.32
2-Jun	48	3.11	4.15	26.89	337.46	80.98
3-Jun	20	4.43	5.69	67.57	295.85	90.66
4-Jun	42	4.09	4.17	30.20	287.62	70.94
5-Jun	14	3.26	4.03	99.60	324.00	86.71
6-Jun	18	5.46	5.28	74.54	339.72	74.82
7-Jun	17	12.43	13.11	67.37	382.29	78.63
8-Jun	34	5.22	5.26	35.51	344.62	80.90
9-Jun	34	5.80	7.11	33.89	293.41	79.44
10-Jun	34	4.68	4.37	37.67	312.53	65.16
11-Jun	36	5.76	4.55	31.92	255.14	58.72
12-Jun	24	4.43	4.10	53.56	300.38	64.02
13-Jun	14	3.93	4.44	98.93	317.79	74.38
14-Jun	30	5.59	5.32	39.48	284.37	63.91
15-Jun	39	5.53	5.59	31.39	309.90	69.16
16-Jun	26	5.66	4.43	46.75	286.00	61.26
17-Jun	8	11.31	15.99	168.69	320.38	81.77
18-Jun	27	4.22	3.69	44.90	153.22	52.99

	Cycles	Duration	Ah	Between	Imax	Iavg
		min	Ah	min	Amps	Amps
19-Jun	33	6.05	5.15	37.58	348.58	63.70
20-Jun	25	6.99	6.16	40.42	316.80	86.92
21-Jun	38	3.50	4.04	34.40	324.21	72.03
22-Jun	17	6.78	7.37	65.03	208.82	61.49
23-Jun	36	5.47	4.67	34.53	331.92	68.54
24-Jun	34	5.90	4.00	28.57	292.56	57.57
25-Jun	22	5.30	5.25	60.15	320.41	71.92
26-Jun	22	9.65	9.71	55.81	222.59	67.05
27-Jun	8	2.80	2.46	158.06	187.38	52.29

Table 5 shows that during the observed time interval, there were seven days with no data collected (see footnote 1). For every other day, data on the table are average values. The second column in Table 5 contains the number of drive cycles for that day. The number of drive cycles per day varies from 2 cycles to 48 cycles, which is shown graphically in Figure 13. Although some data for the month of May are missing, the graph shows a gradual increase in the number of drive cycles over the observed period.

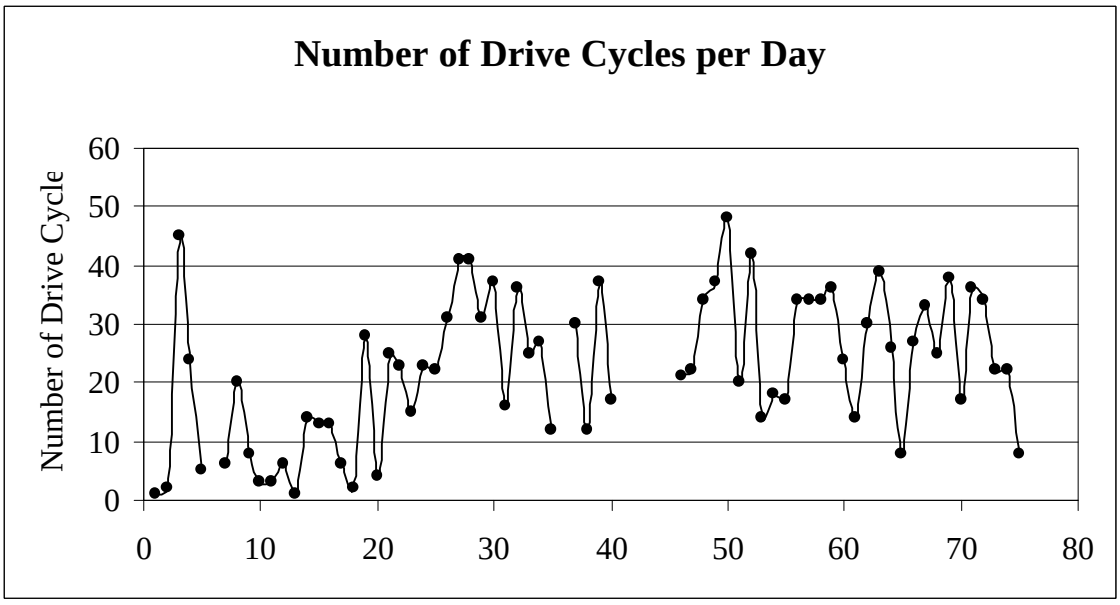


Figure 13. Number of Drive Cycles over the Observed Period

Drive Cycles per Day

Figure 14 shows that the number of drive cycles increased at the rate of ~ 0.23 drive cycles per day. Trend line also shows that over the data collection period, the average number of drive cycles more than doubled, from 13 drive cycles per day at the beginning to over 30 drive cycles per day.

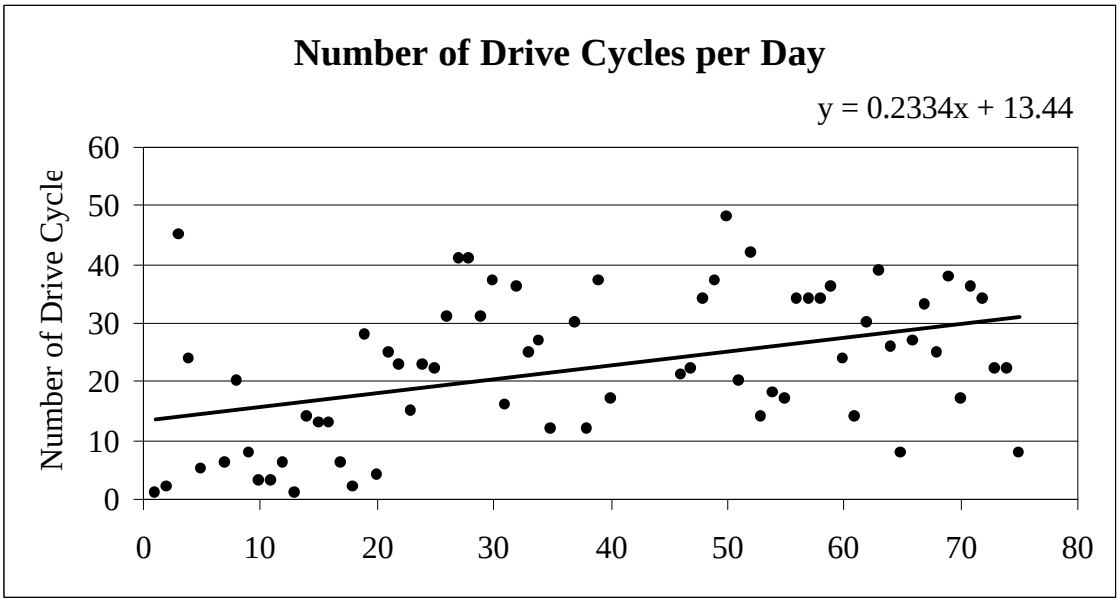


Figure 14. Trend Line for the Number of Drive Cycles

Figure 15 contains a Histogram showing the distribution of the number of drive cycles per day, given on Figure 15, shows that in most of the days there were 25 drive cycles.

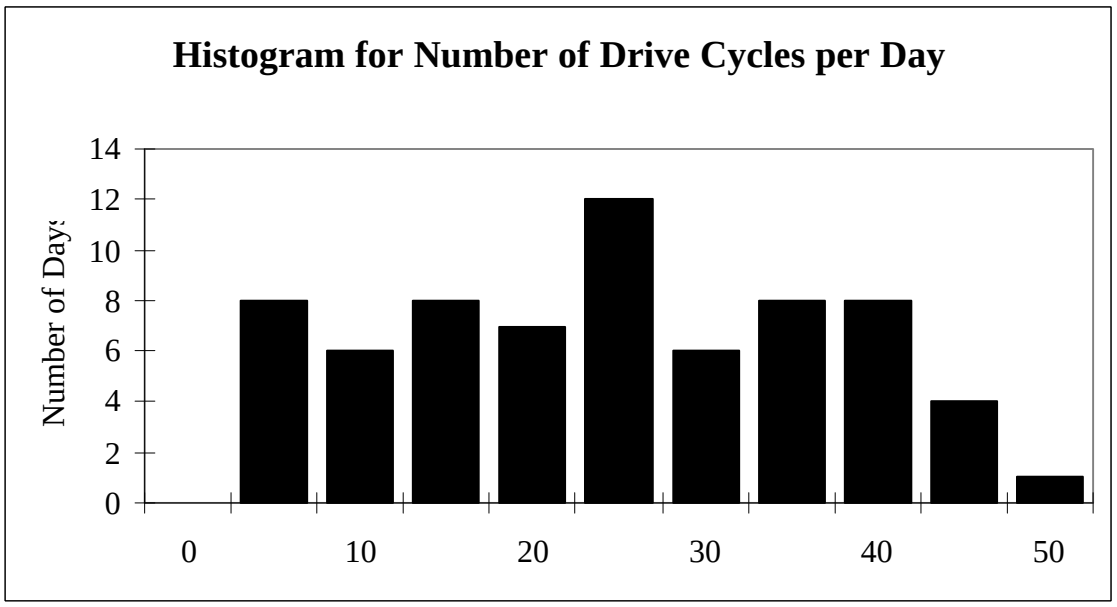


Figure 15. Histogram for the Number of Drive Cycles per Day

Average Drive Cycle Duration

The third column in Table 5 shows the average duration of drive cycles per day. This average varies from a low of 0.93 minutes to a high of 12.43 minutes, and is shown graphically in Figure 16. Although some data for the month of May are missing, the graph none-the-less shows a gradual increase in the number of drive cycles over the observed period. Figure 17 shows that the number of drive cycles increased at the rate of 0.048 minutes per day. A trend line shows that the average duration of daily drive cycles doubled over the observed period: from just under 3 minutes per drive cycle at the beginning to over 6 minutes per drive cycles by the end of observed period.

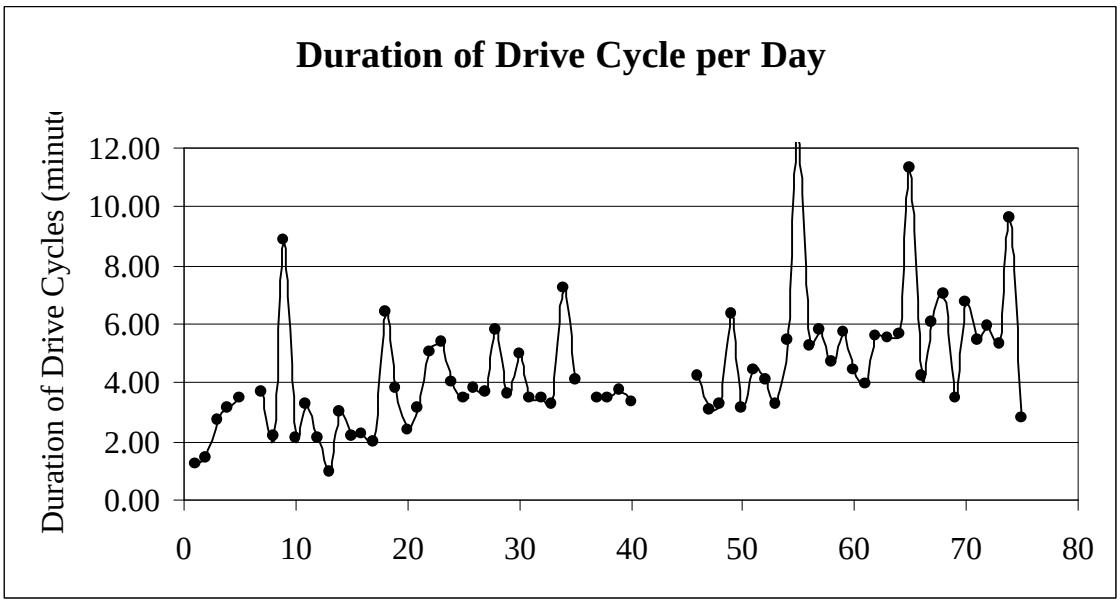


Figure 16. Average Duration of Drive Cycles per Day

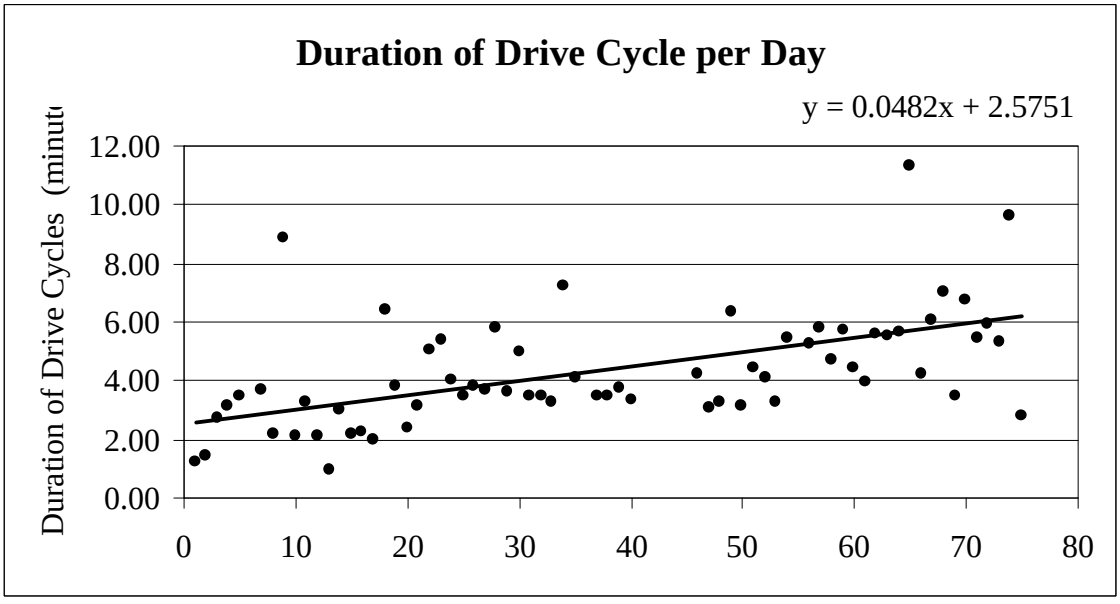


Figure 17. Trend line for Average Duration of Drive Cycles per Day

A Histogram for Drive Cycle duration shows that while most drive cycles were between 2 and 7 minutes in duration, the majority of drive cycles had a duration of 4 minutes.

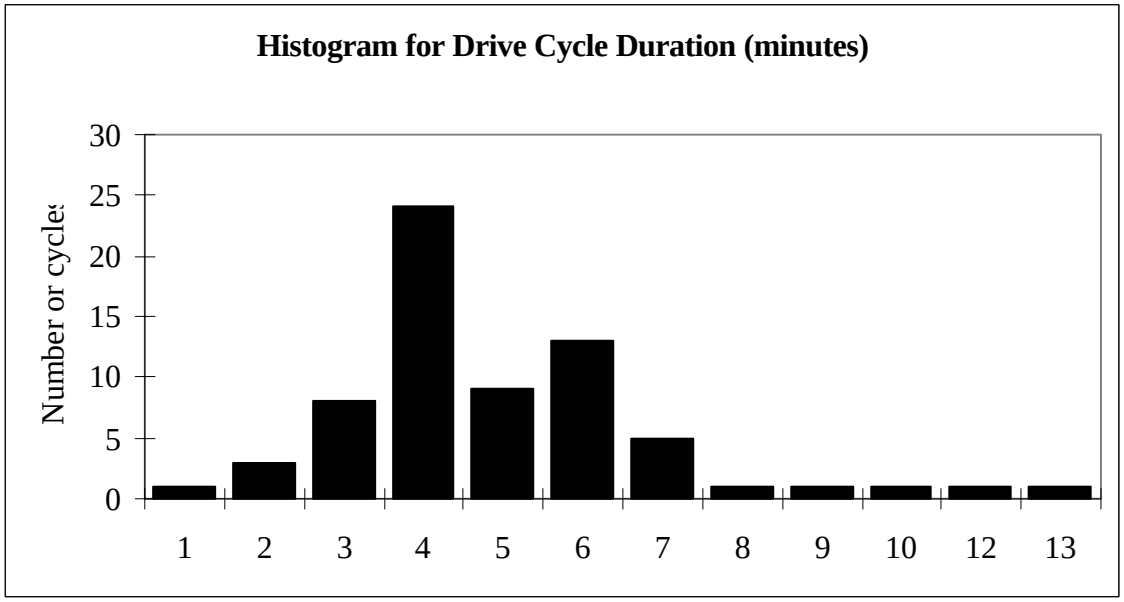


Figure 18. Histogram for Drive Cycle Duration

The fifth column in the Table 5 shows the average time between drive cycles each day. The averages, which vary from a low of 25.44 minutes to a maximum of 1439 minutes are given in Figure 19. Although some data for the month of May are missing, the graph shows a gradual decrease in the average number of drive cycles over the observed period. This can be attributed to both the increased number of drive cycles per day, and lessening skew effect of the extremely high wait times at the beginning of the observation period. Figure 20 shows that the average time between drive cycles decreased at the rate of ~ 5.1 minutes per day. The trend line also shows that the average time between drive cycles decreased over 10 times over the observed period.

To better evaluate the data without the deleterious effects of skewing from four extremely high datum, those four points were removed from the data set, and the graph recast. The results are contained in Figures 21 and 22.

Average Time Between Drive Cycles – Unmodified

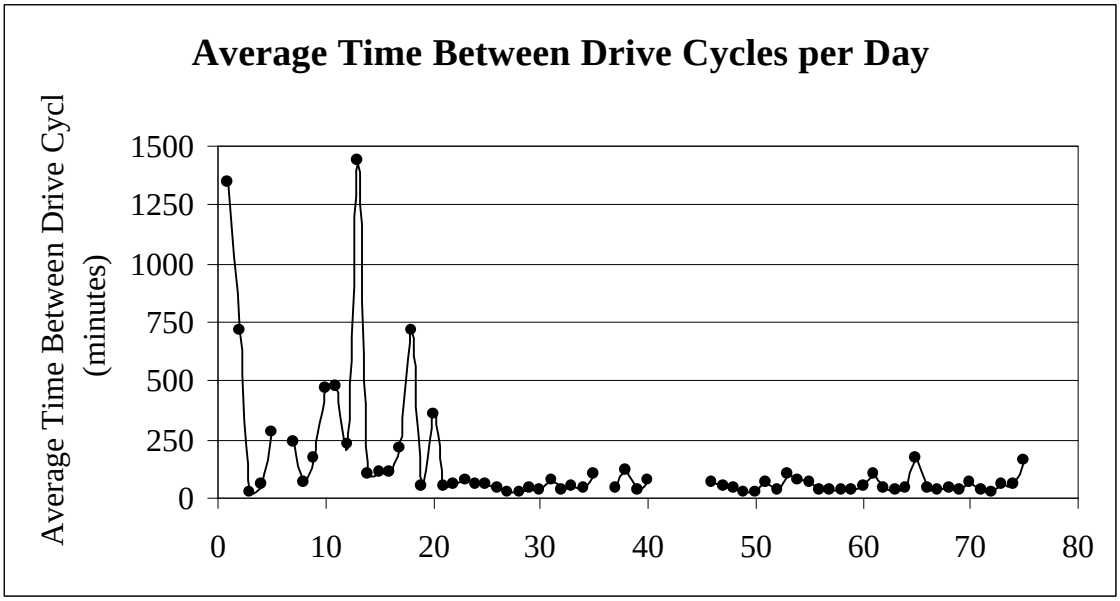


Figure 19. Average time between drive cycles per day over the observed period

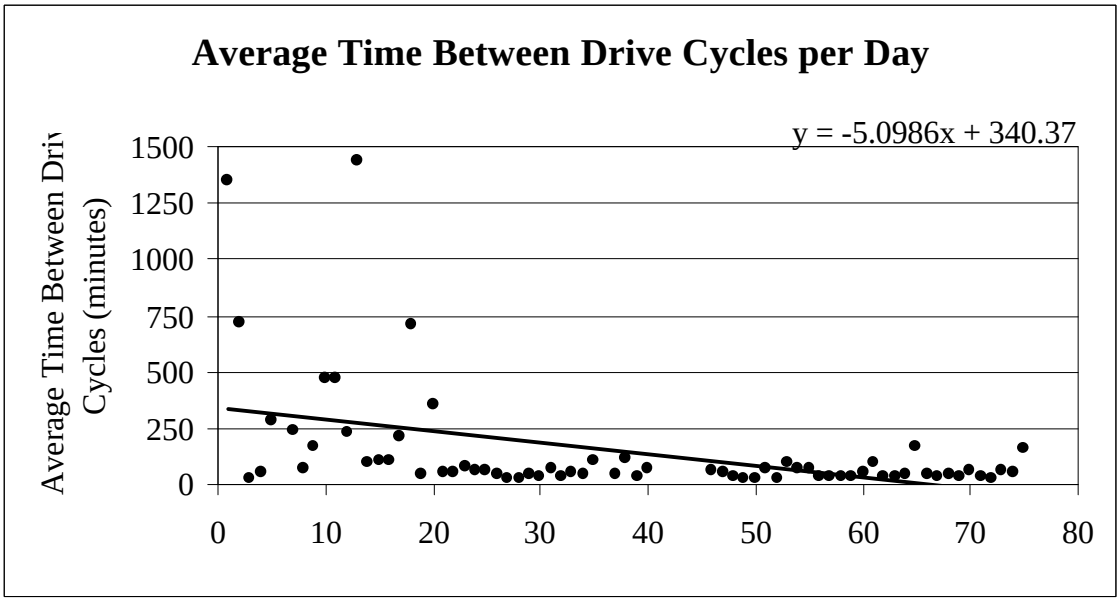


Figure 20. Trend line for average time between drive cycles per day

Modified Average Drive Cycles

When the four points greater than 300 minutes are ignored, the trend line for time between two drive cycles is given on Figure 21.

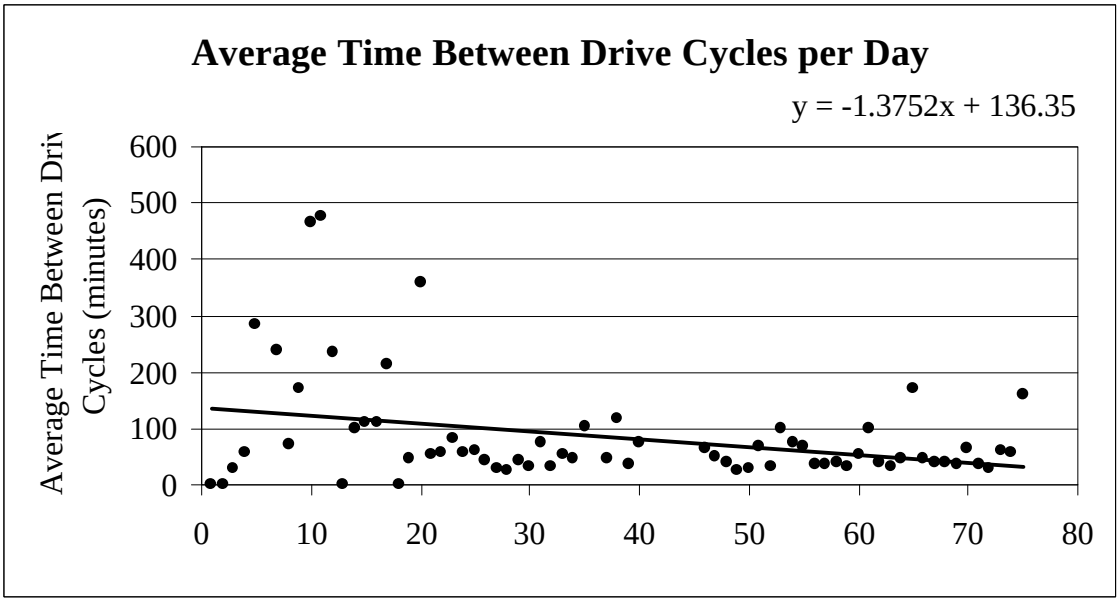


Figure 21. Trend Line for Time Between Drive cycles

A histogram for the time between two drive cycles, shown in Figure 22, indicates that the majority of time, the time between drive cycles was between 40 minutes and 80 minutes.

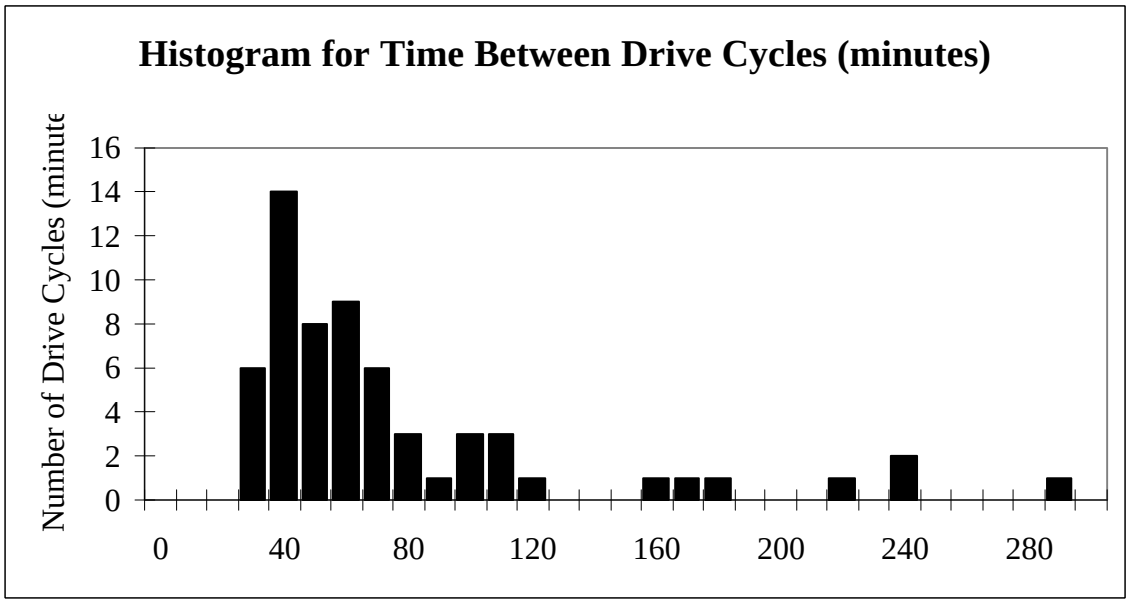


Figure 22. Histogram for Time Between two Drive Cycles

Ampere-Hours (Ah) per Drive Cycle

The fourth column in the Table 5 gives the average Ah's used in a drive cycles per day. The average varied from a low of 0.45 Ah to a maximum of 15.99 Ah and is shown in Figure 23. Although some data for the month of May are missing, the graph shows a gradual decrease in Ah's used per cycle per day over the observed period. Figure 24 shows that the average Ah's used increased at the rate of ~ 0.05 Ah per drive cycle per day. A trend line also shows that the average Ah's used per drive cycle doubled over the observed period.

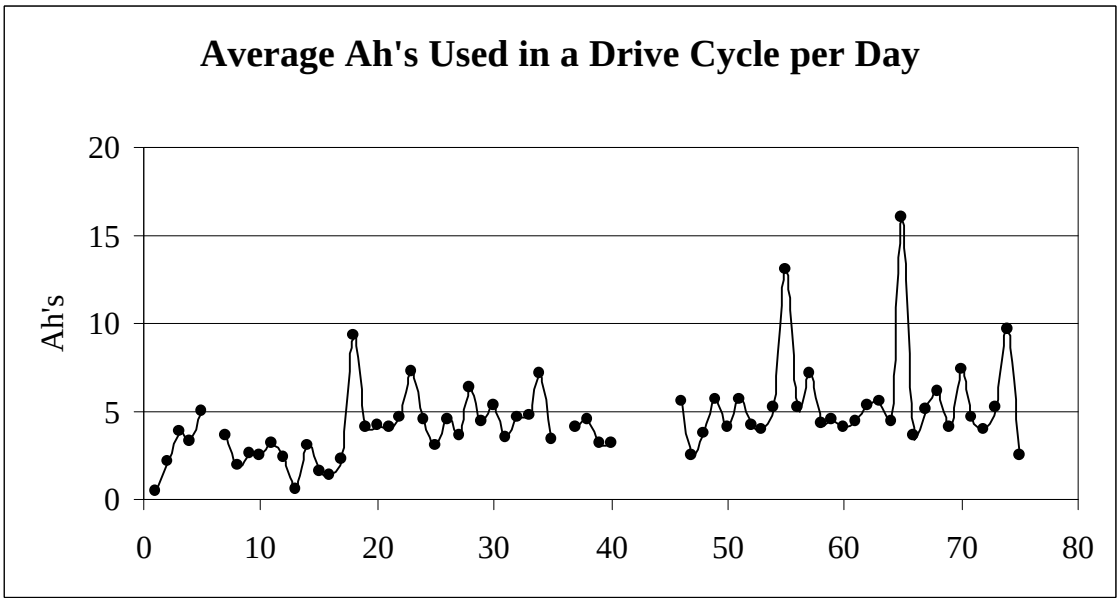


Figure 23. Average Ah's Used in a Drive Cycle per Day

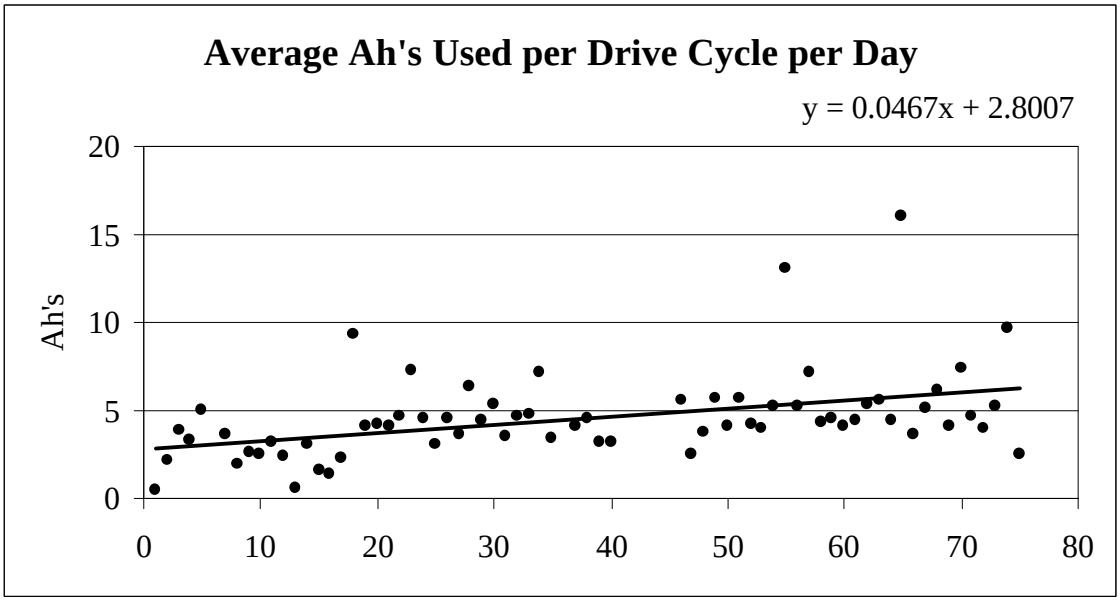


Figure 24. Trend Line for Average Ah's Used in a Drive Cycle per Day

Figure 25 is a Histogram for Ah's used per drive cycle, and shows that the typical drive cycle used between 4 Ah and 6 Ah.

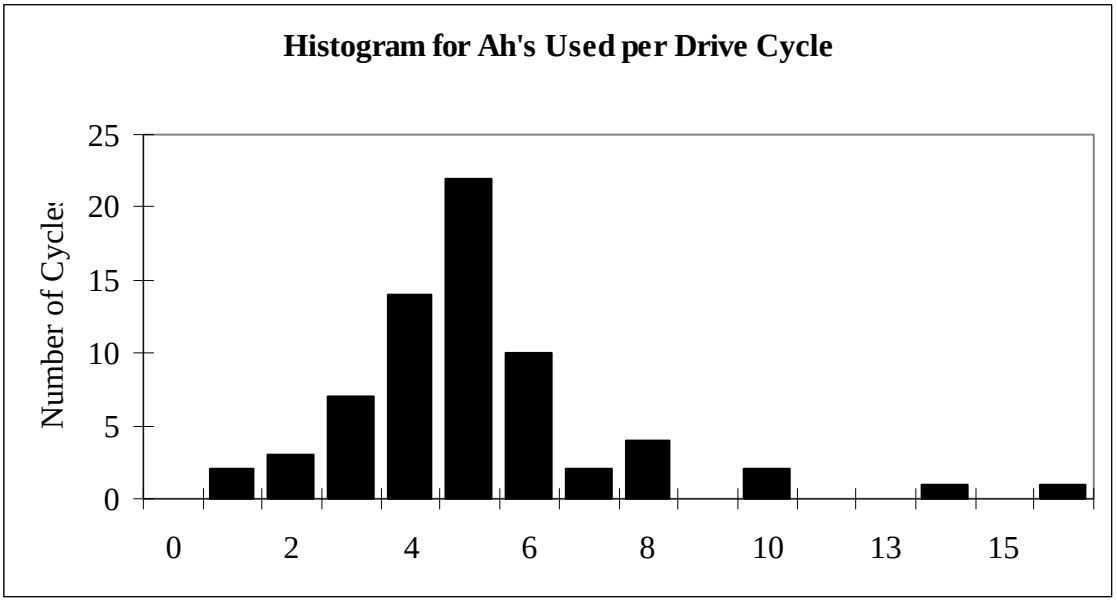


Figure 25. Histogram for Ah's Used

AVERAGE CHARGE AND DISCHARGE DATA FOR PROJECT

The average values for the charge and discharge cycles were determined for the entire observed period. Table 5 shows average charge data, while Table 6 shows average discharge data.

TABLE 5

Charge Time	Average Current	Capacity In	$V_{INITIAL}$	V_{FINAL}	$V_{INITIAL}$ - V_{FINAL}	$T_{INITIAL}$	T_{FINAL}	$T_{INITIAL}$ - T_{FINAL}
min	Amps	Ah	Volts	Volts	Volts	^{o}C	^{o}C	^{o}C
114.80	169.15	256.16	81.95	97.16	15.21	31.60	54.83	22.54

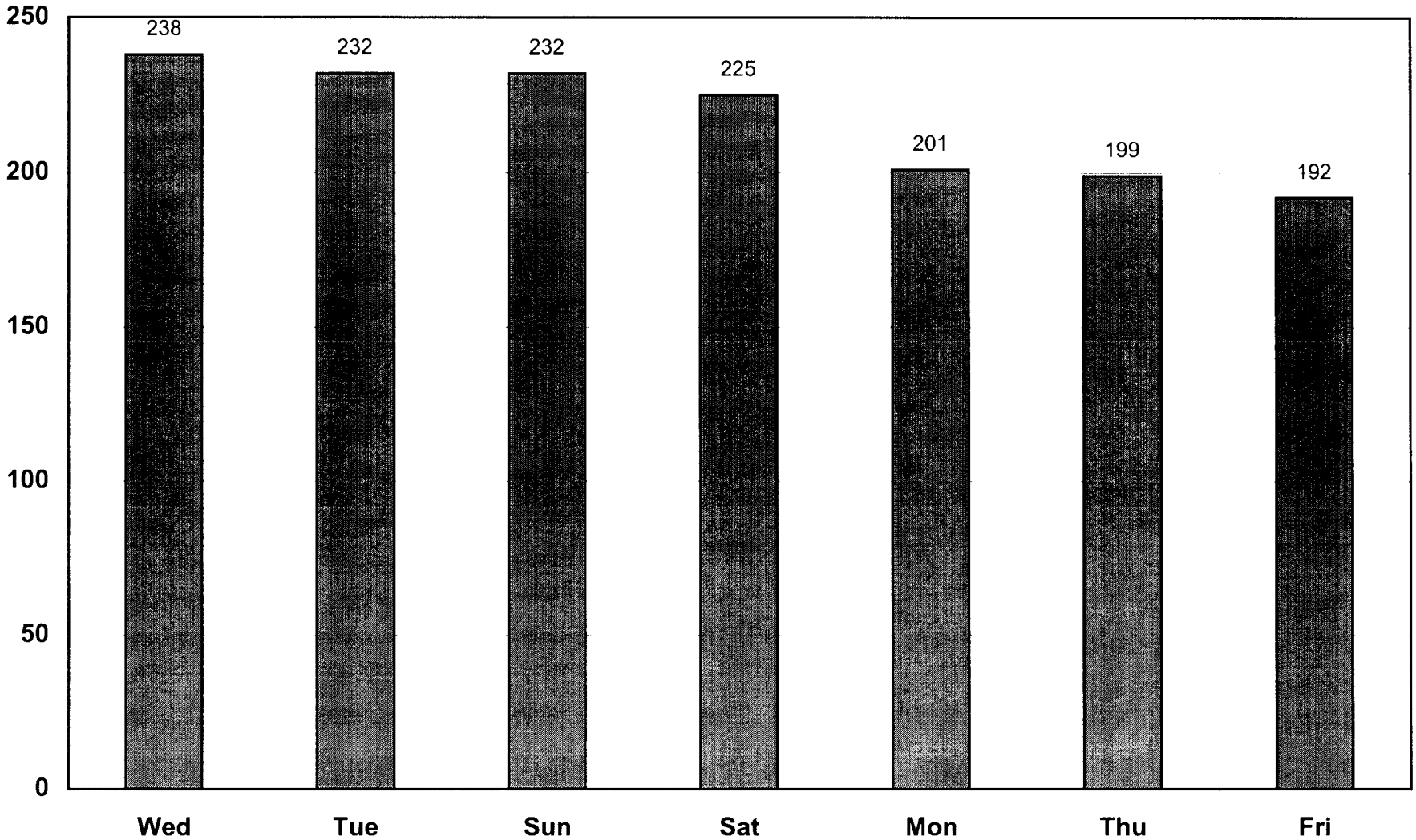
TABLE 6

Average Number of Cycles per Day	Average Duration of Cycle	Average Ampere-hours used per Cycle	Average Time Between Cycles	Average Current for Cycle
	minutes	Ah	minutes	Amps
22	4.41	4.58	147.29	68.94

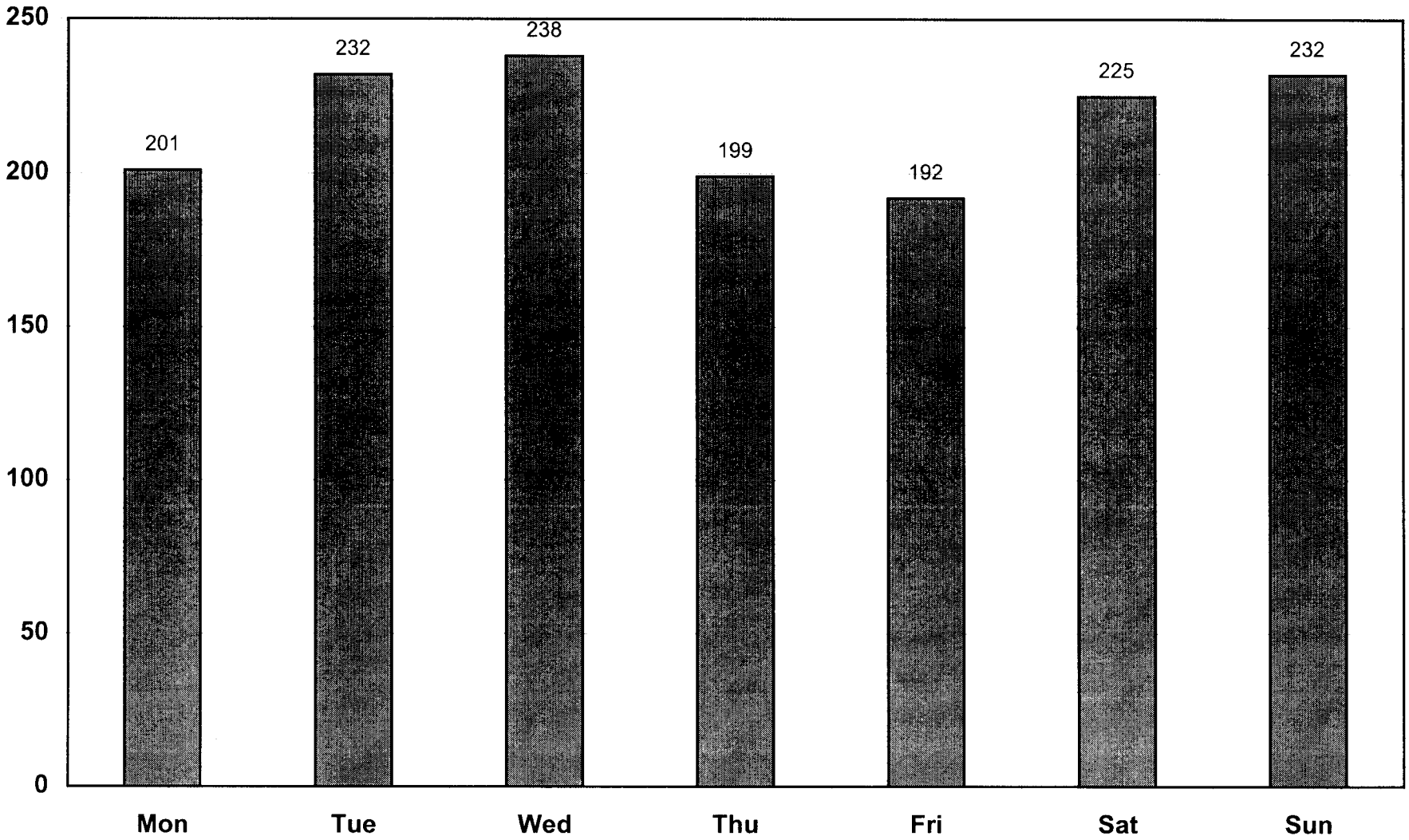
CONCLUSION

Based upon these averages, the average tractor can expect a normal discharge per day of approximately 101 Ah, or approximately 26% of it's available battery capacity. The vehicles used in this project were outfitted with discharge limit devices to prevent discharging the battery below 30% of nominal capacity. Therefore, the tractor will consume approximately 30% of its rated capacity per day. However, the SuperCharge only charges the battery to ~80% State of Charge. This reduces the available energy to 50% (80% of nominal capacity – 30% lower SOC lower Limit). If the tractor consumes ~101 Ah per day, this equates to ~42% available capacity per day. This means the tractor could theoretically operate for two full days between charges. This is consistent with the data for all the tractors, which indicates the charger completes slightly less than 7 charges per day for a population of 12 electric bag tractors.

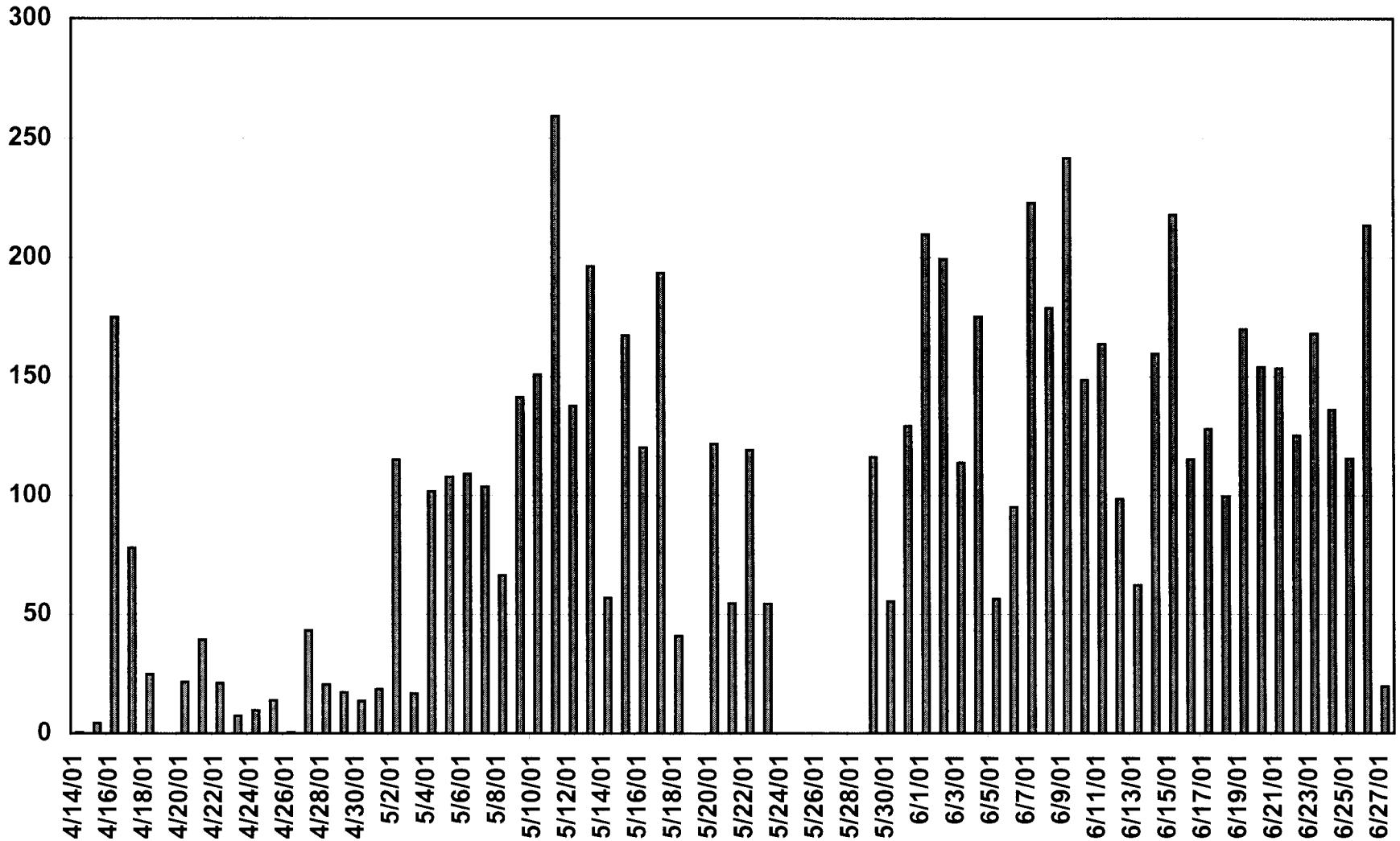
Cycles Per Day By Highest Usage - Vehicle BTE-06



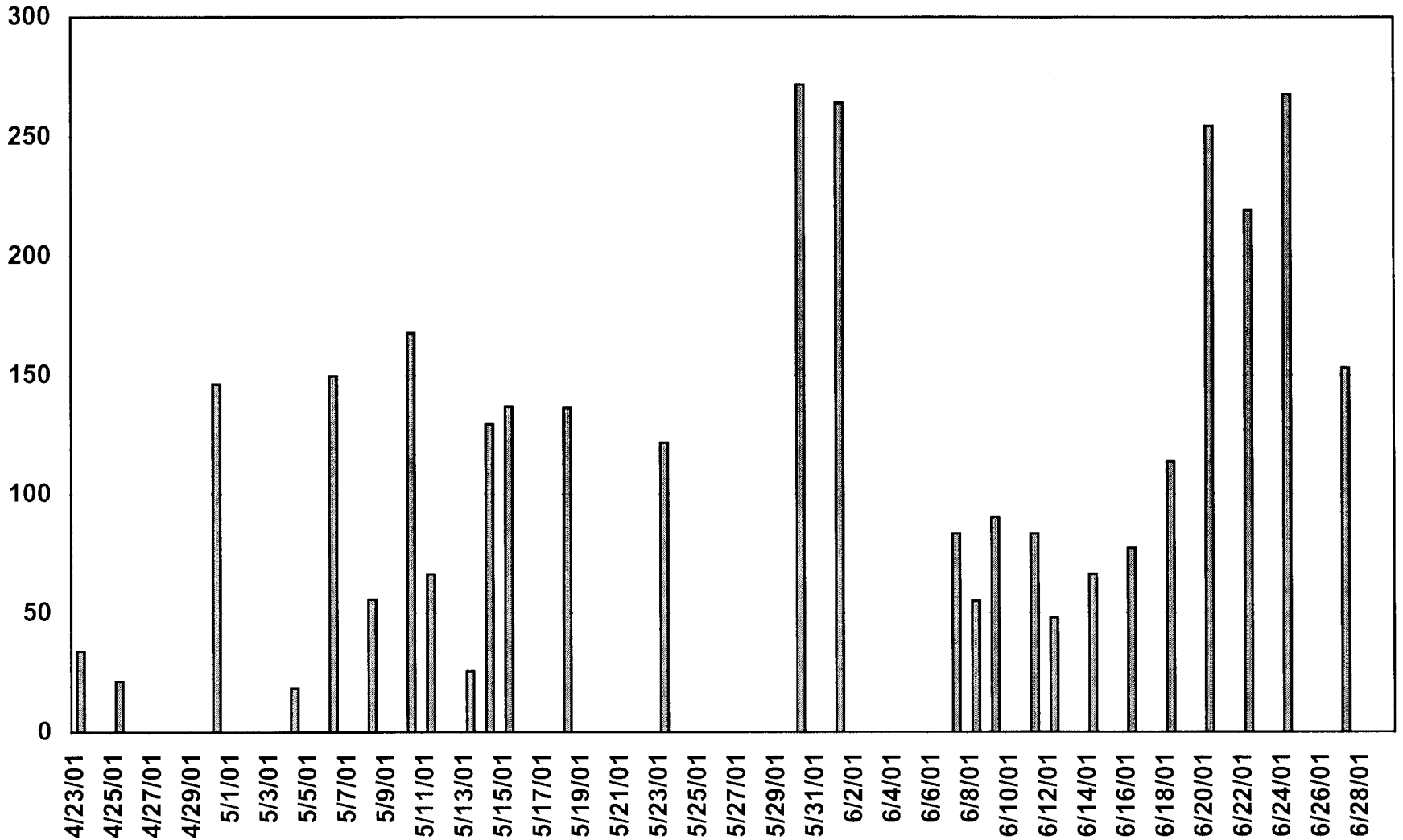
Total Cycles per Day of Week - Vehicle BTE-06



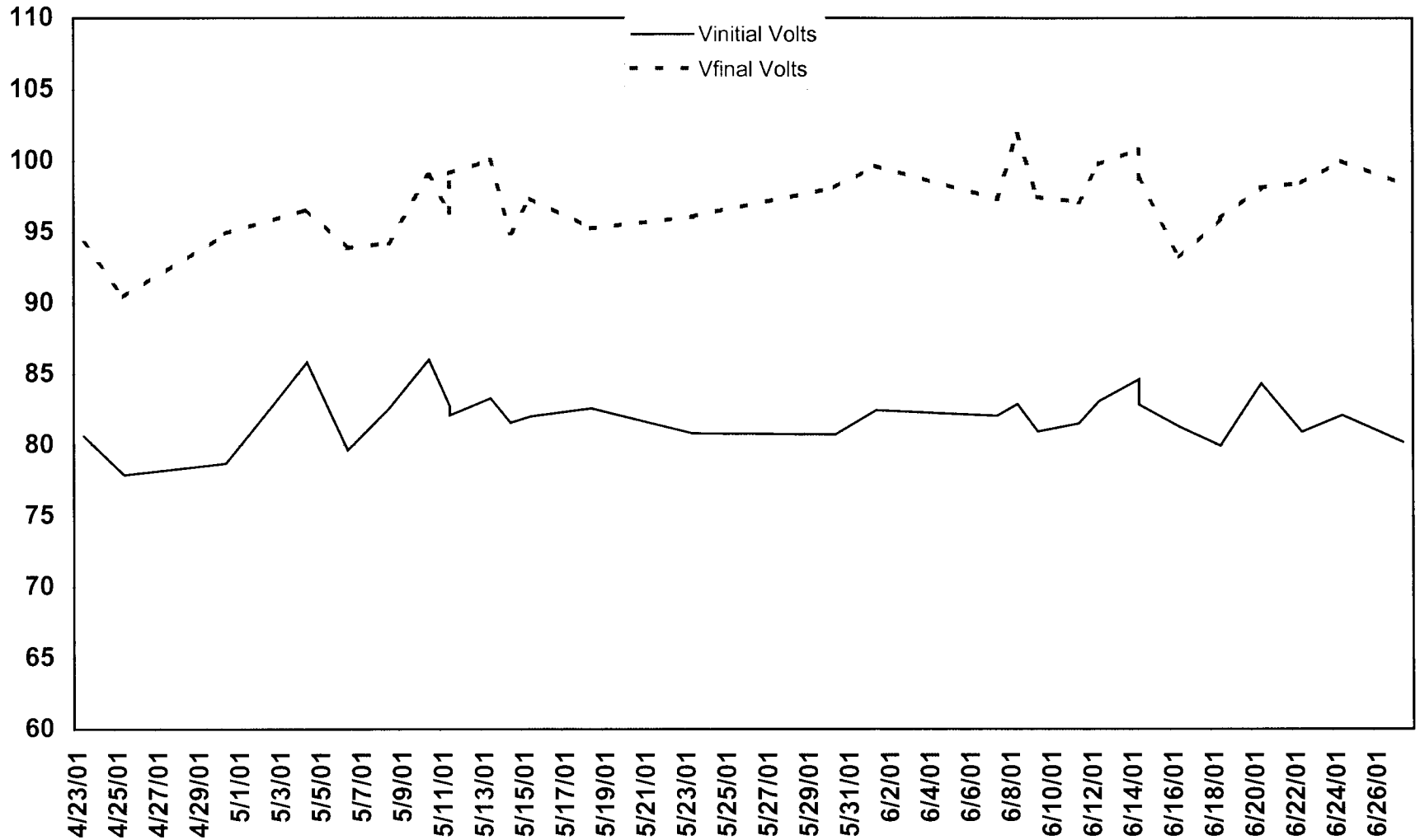
Ampere-hours Used per Day - Vehicle BTE-06



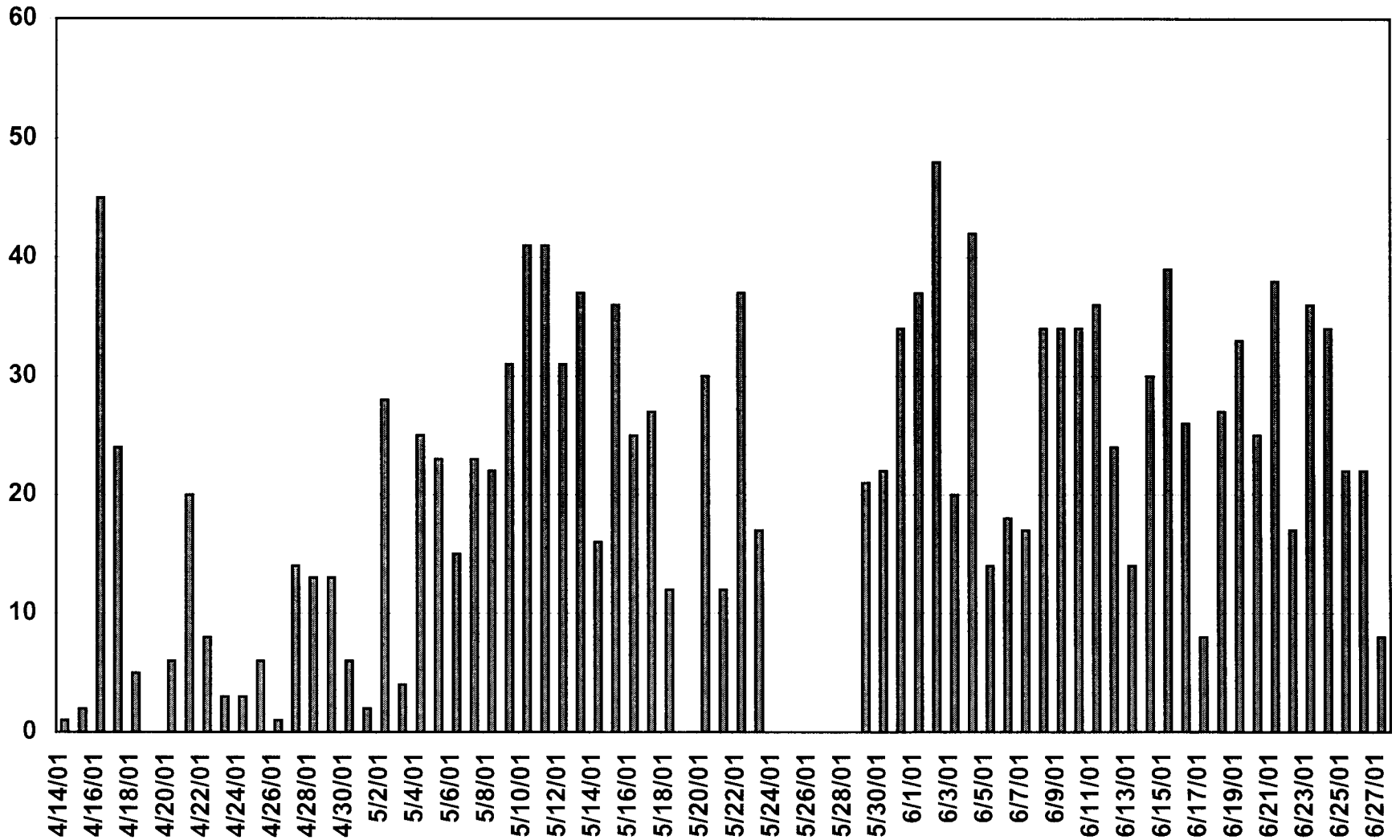
Time on Charge (from on-board DAQ) - Vehicle BTE-06

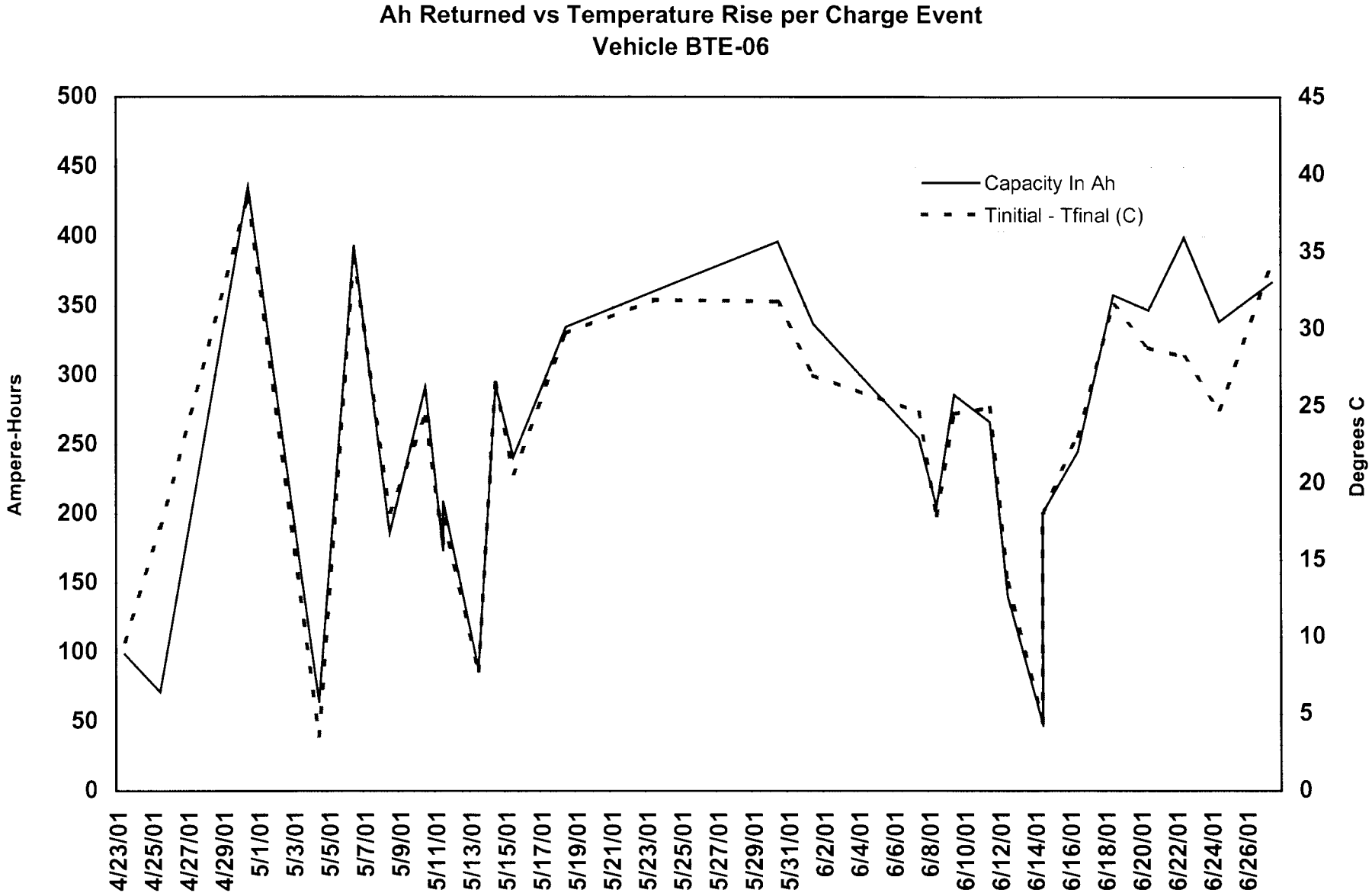


Battery Charge Voltage - Initial vs Final
Vehicle BTE-06



Drive Cycles per Day - Vehicle BTE-06




Ah Returned vs Temperature Rise per Charge Event
Vehicle BTE-06
Capacity In Ah
Tinitial - Tfinal (C)
Ampere-Hours
Degrees C
500
450
400
350
300
250
200
150
100
50
0
45
40
35
30
25
20
15
10
5
0
4/23/01
4/25/01
4/27/01
4/29/01
5/1/01
5/3/01
5/5/01
5/7/01
5/9/01
5/11/01
5/13/01
5/15/01
5/17/01
5/19/01
5/21/01
5/23/01
5/25/01
5/27/01
5/29/01
5/31/01
6/2/01
6/4/01
6/6/01
6/8/01
6/10/01
6/12/01
6/14/01
6/16/01
6/18/01
6/20/01
6/22/01
6/24/01
6/26/01

APPENDIX E

POWER QUALITY REPORTS

Power Analysis A13 ETEC Charger 7-Day Monitoring

Introduction

This is a summary of the power conditions at the SMF site, recorded at the SuperCharge battery charger located at Gate A13. Data at this location was collected between 13:35:46 on March 8, 2001 through 09:00:00 on March 14, 2001.

This summary is composed of:

- The initial conditions section, wihch defines the power conditions at the above location**.**
- The Events section, a summary of the voltage events that occurred at this location during the monitor interval. Events are defined as changes in the monitored voltage. These changes may be subtle or severe. The power tolerance curve provides a graphical representation of the likelihood of an event to disrupt equipment operations.
- The Voltage Current and Frequency (VIF) section, which contains summaries for each of these parameters during the monitoring interval.
- The Harmonics section, which contains the voltage and current harmonics, and harmonic distortion summaries acquired during the monitoring interval.
- The Power section, which contains the VA, VARS, Watts, and Power factor acquired during the monitoring interval. For multiphase locations, voltage and current imbalances are also included.

Site and Location Information

Site Information

Name	SMF
Date and Time	12/01/00 09:54:49

Location Information

Name	A13 ETEC Battery Charger
Power Type	Three phase delta
Feed Phase	480V
Date and Time	03/14/01 09:48:52
Nominal Frequency	60 Hz

Report Parameters

This report was prepared on 03/19/01. The following limits were used in analyzing the results.

Maximum Phase Voltage.	504 V
Minimum Phase Voltage.	456 V
Maximum Impulse Voltage.	500 V
Maximum. Waveshape Voltage.	10 V
Maximum Frequency Deviation.	.02 Hz
Minimum Power Factor.	.8
Maximum Voltage T.H.D.	5 %
Maximum Current T.H.D	350 %
Maximum Voltage Imbalance.	2 %
Maximum Current Imbalance.	200 %

Any values outside these limits are noted in the report. Values within the limits are considered to be within a safe operating range.

Initial Conditions

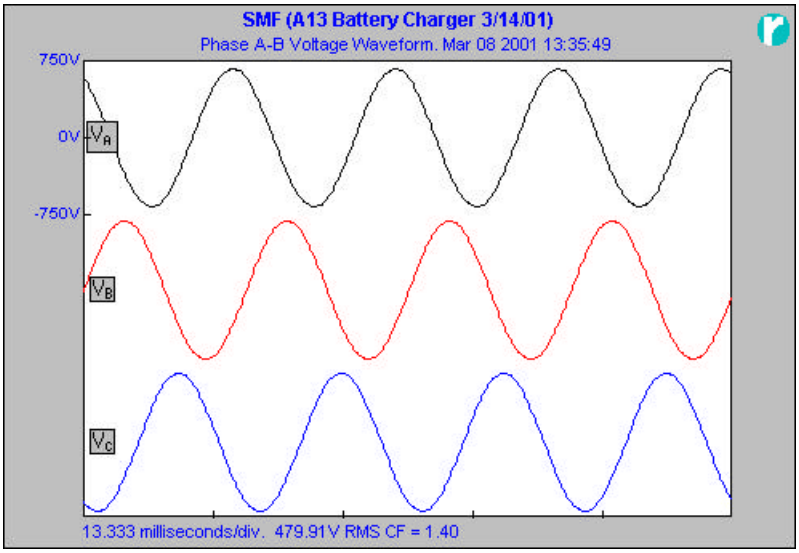
The summary of all the electrical parameters at this location is presented in the tables and graphs below. Parameters marked with an '*' lie outside the limits defined above.

Initial Power measurements for SMF A13 Battery Charger, 03/14/01 at 09:48:52

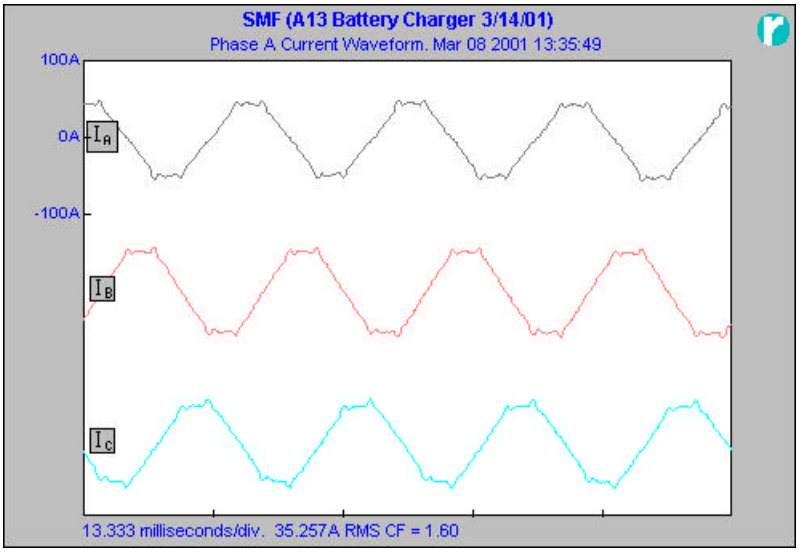
Measurement	Phase A	Phase B	Phase C
True RMS. Voltage	479.9V	480.5V	480.9V
Max. Peak to Peak Voltage	1.350kV	1.354kV	1.356kV
True RMS. Current	35.25A	40.47A	37.85A
Max. Peak to Peak Current	105.1A	118.8A	117.1A
Fundamental RMS. Voltage	479.8V	480.4V	480.9V
Voltage Angle	0°	240.1°	120.1°
Fundamental RMS. Current	34.86A	40.05A	37.77A
Current Angle	351.5°	231.3°	103.7°
Fundamental Impedance	7.954 Ohms	6.918 Ohms	7.351 Ohms
Impedance Angle	8.487°	8.769°	16.38°
Voltage Imbalance	0.12%		
Current Imbalance	7.18%		
Total Voltage Harmonics	0.952%	0.874%	0.990%
Total Current Harmonics	8.855%	7.595%	8.022%
True VA	9.700k	11.16k	10.52k
True VARS.	1.480k	1.929k	2.924k
True Watts	9.587k	10.99k	10.11k
Distortion	24.17	26.53	48.74
True Power Factor	0.988	0.984	0.960
Fundamental VA	9.668k	11.09k	10.49k
Fundamental VARS.	1.427k	1.692k	2.959k
Fundamental Watts	9.562k	10.96k	10.06k
Fundamental Power Factor	0.989	0.988	0.959

The Initial Conditions are within the limits defined above.

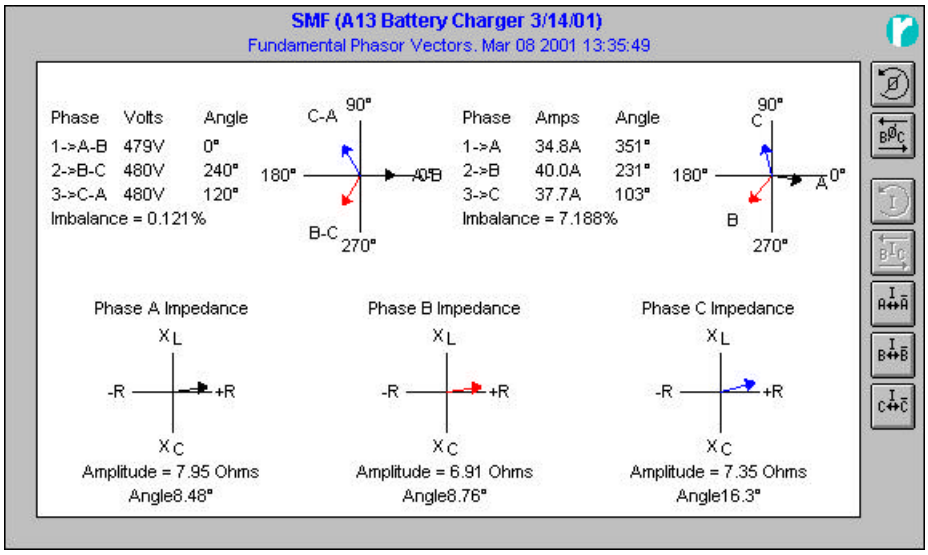
The Voltage waveforms for SMF A13 Battery Charger are shown below:



The Current waveforms for SMF A13 Battery Charger are shown below:



The Voltage, Current and Impedance Phasors for SMF A13 Battery Charger are shown below:



Voltage Events

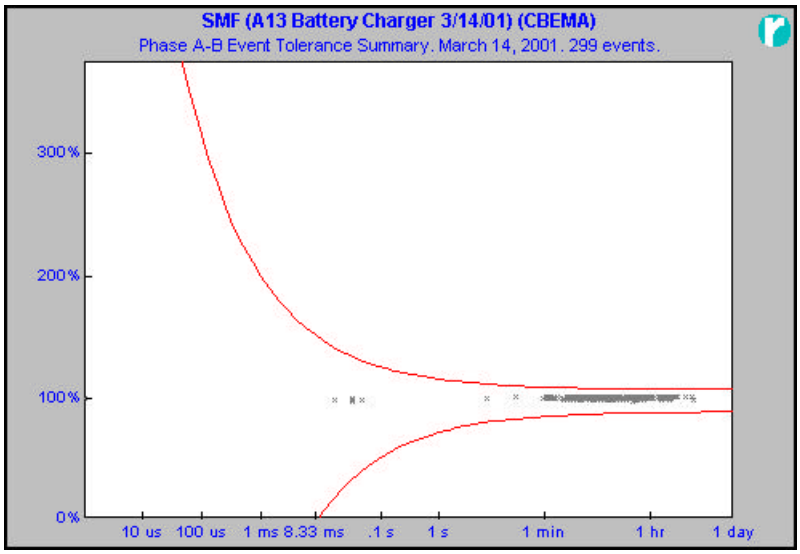
The following summarizes the results of the Power Quality monitoring survey from 03/08/01 13:35:46 through 03/14/01 09:00:00. It is intended to present an overview of the power quality at SMF:A13 Battery Charger 3/14/01. The table below is a listing of the most significant events.

Event Description	No.	Amp.	Duration	Date and Time
Phase A Largest RMS. Event	1600	467.0V	30.225 min	Mar 10 2001 04:30:18
Phase A Largest Waveshape Event	4940	466.5V	33.333 ms	Mar 13 2001 05:49:51
Phase A Longest Waveshape Event	900	474.8V	50 ms	Mar 09 2001 12:14:25
Phase A Largest Impulse Event	N/A			
Phase A Longest Impulse Event	N/A			
Phase B Largest RMS. Event	1241	468.0V	1.182 hr	Mar 10 2001 04:30:18
Phase B Largest Waveshape Event	3971	466.7V	33.333 ms	Mar 13 2001 05:49:51
Phase B Longest Waveshape Event	4051	471.9V	66.667 ms	Mar 13 2001 07:47:05
Phase B Largest Impulse Event	N/A			
Phase B Longest Impulse Event	N/A			
Phase C Largest RMS. Event	522	468.5V	10.767 hr	Mar 09 2001 22:00:10
Phase C Largest Waveshape Event	1522	464.0V	16.667 ms	Mar 12 2001 14:55:13
Phase C Longest Waveshape Event	262	468.0V	33.333 ms	Mar 09 2001 12:14:25
Phase C Largest Impulse Event	N/A			
Phase C Longest Impulse Event	N/A			

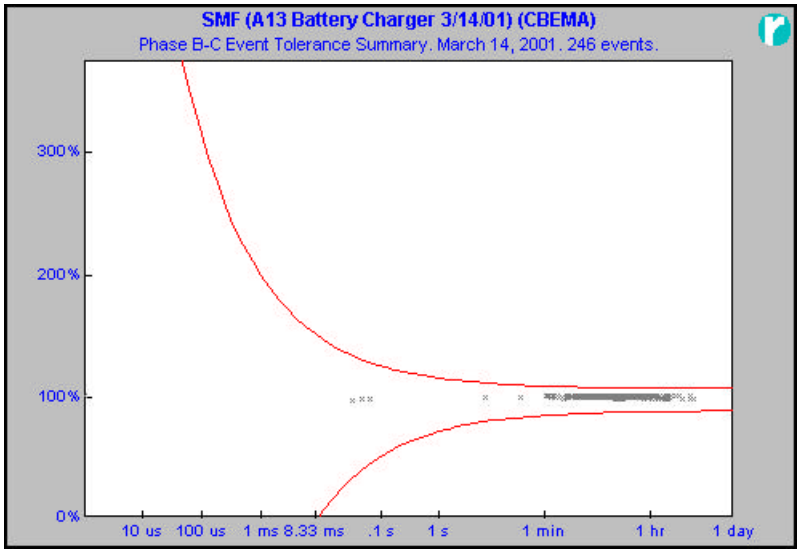
Power Tolerance Envelope

The power quality parameters are summarized in the Power Tolerance Envelope shown below. Each dot on these graphs represents an event. The areas outside of these lines depict events which are often associated with equipment malfunction. **No significant voltage events occurred during the monitoring period.**

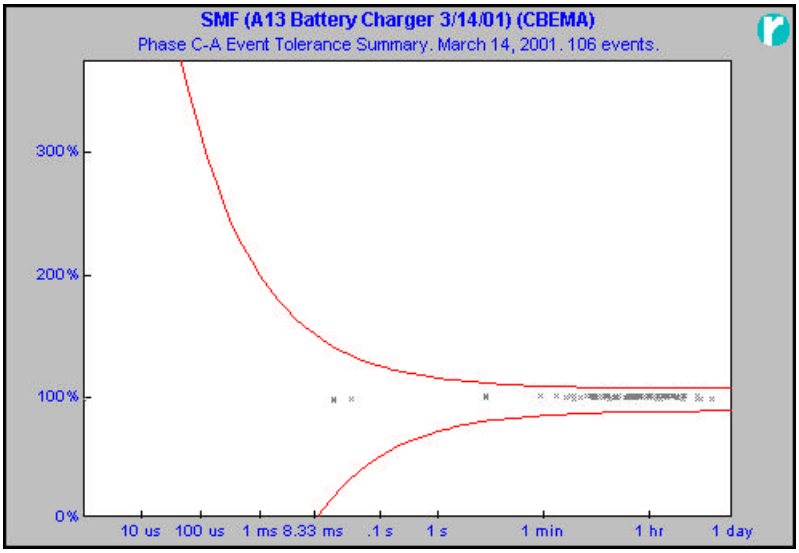
Phase A Event Tolerance Summary



Phase B Event Tolerance Summary



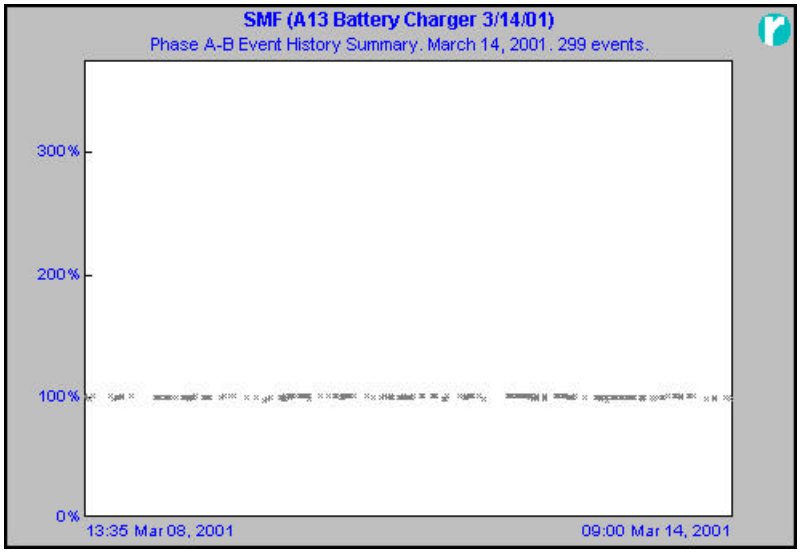
Phase C Event Tolerance Summary



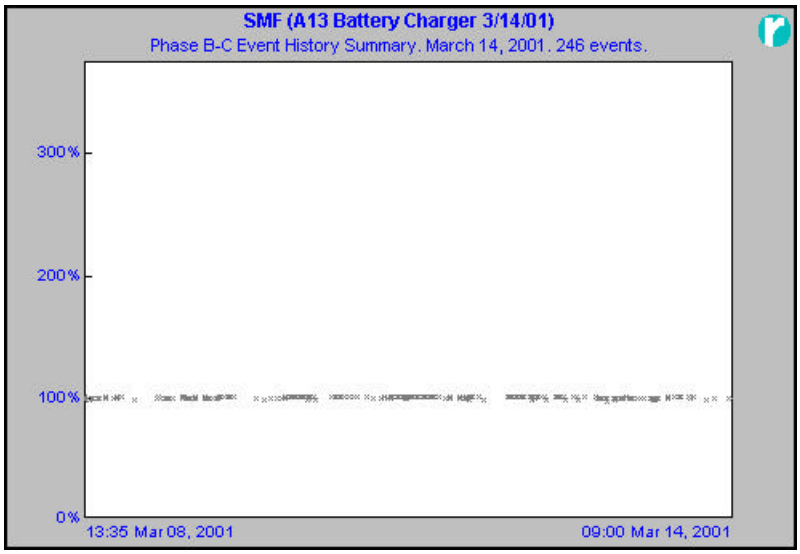
Event History Graphs

A summary of events that occurred during the monitoring interval is shown in the event history graphs below. These events are graphed by amplitude versus time of occurrence.

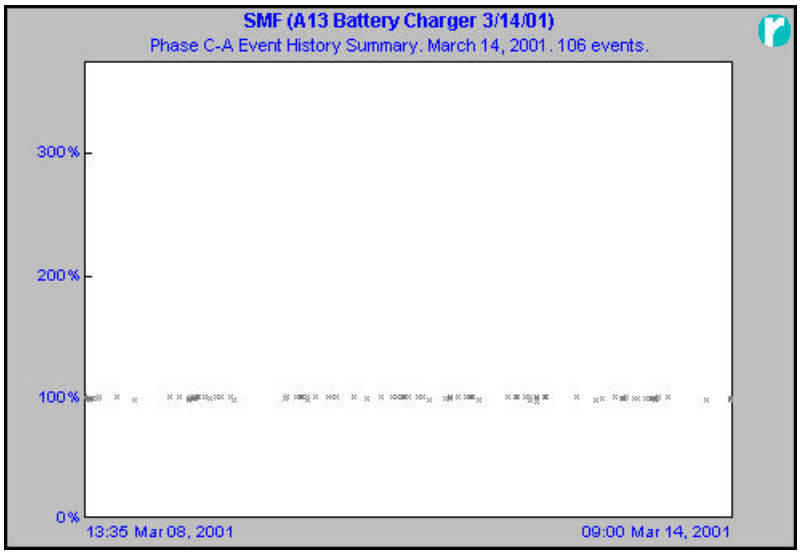
Phase A Event History Summary



Phase B Event History Summary



Phase C Event History Summary



Impulses

Impulses are shown on the left side of the Power Tolerance Envelope. They are relatively high frequency voltage excursions of short duration. When these disturbances are of significant magnitude and duration, they can cause malfunction of sensitive electronic equipment and damage both components and insulation. **No significant Impulse Events occurred during the monitoring period.**

Waveshape Faults

Waveshape faults are longer in duration than impulses and are shown in the middle of the Power Tolerance Envelope. They are often sub-cycle distortions of the AC sinusoid. However, these distortions can last for a fraction of the single cycle period or they can continue for hundreds of milliseconds, hours or even days. All equipment which is not supplied by an Uninterruptible Power Supply, or whose power supply doesn't inherently have sufficient "ride through" to withstand this type of disturbance will be disrupted. Frequently these disturbances are associated with impulses. **No significant Waveshape Faults occurred during the monitoring period**

Voltage Swells and Sags

The utility strives to keep RMS levels within a +5%, -5% range of the nominal voltage. Swells are those events when RMS levels rise above the +5% range. Sags are those events when RMS levels go below the -5% range. Duration is generally from a few cycles to a few seconds. **No significant RMS Events occurred during the monitoring period**.

Voltage, Current and Frequency Summaries

Voltage, Current and Frequency measurements for SMF A13 Battery Charger from 13:35:46 on March 8, 2001 through 09:00:00 on March 14, 2001.

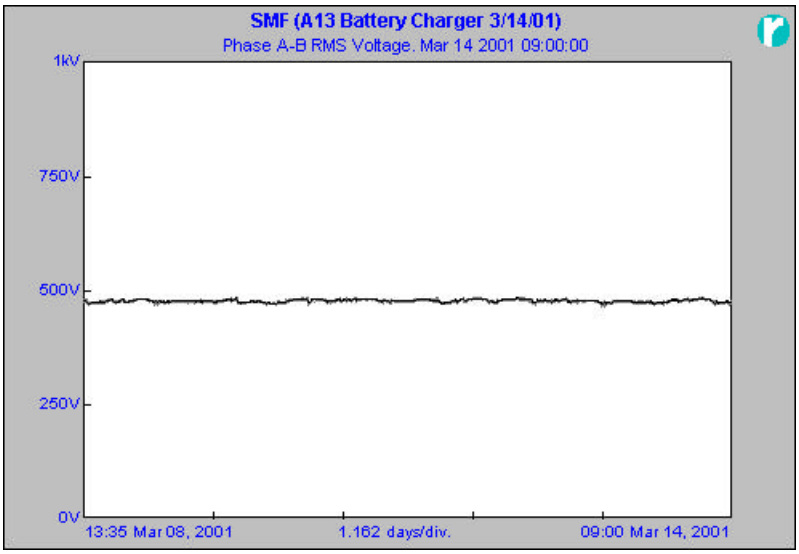
RMS. Voltages	**Value**	**Date and Time**
Phase A minimum	466.5V	Mar 13 2001 04:55:46
Phase A average	**478.7V**	
Phase A maximum	485.9V	Mar 09 2001 22:45:46
Phase B minimum	466.3V	Mar 12 2001 14:45:46
Phase B average	**479.7V**	
Phase B maximum	487.0V	Mar 09 2001 22:35:46
Phase C minimum	463.8V	Mar 12 2001 14:45:46
Phase C average	**480.2V**	
Phase C maximum	487.8V	Mar 09 2001 22:45:46

RMS. Currents	**Value**	**Date and Time**
Phase A minimum	1.648A	Mar 09 2001 08:05:46
Phase A average	**11.03A**	
Phase A maximum	56.76A	Mar 09 2001 22:35:46
Phase B minimum	2.563A	Mar 11 2001 09:45:46
Phase B average	**13.17A**	
Phase B maximum	67.75A	Mar 09 2001 22:35:46
Phase C minimum	2.380A	Mar 08 2001 13:45:46
Phase C average	**12.43A**	
Phase C maximum	53.10A	Mar 09 2001 22:35:46

Frequency	**Value**	**Date and Time**
Phase A minimum	59.93Hz	Mar 11 2001 06:45:46
Phase A average	**59.99Hz**	
Phase A maximum	60.05Hz	Mar 10 2001 13:15:46
Phase B minimum	59.93Hz	Mar 11 2001 06:45:46
Phase B average	**59.99Hz**	
Phase B maximum	60.05Hz	Mar 10 2001 13:15:46
Phase C minimum	59.93Hz	Mar 11 2001 06:45:46
Phase C average	**59.99Hz**	
Phase C maximum	60.05Hz	Mar 10 2001 13:15:46

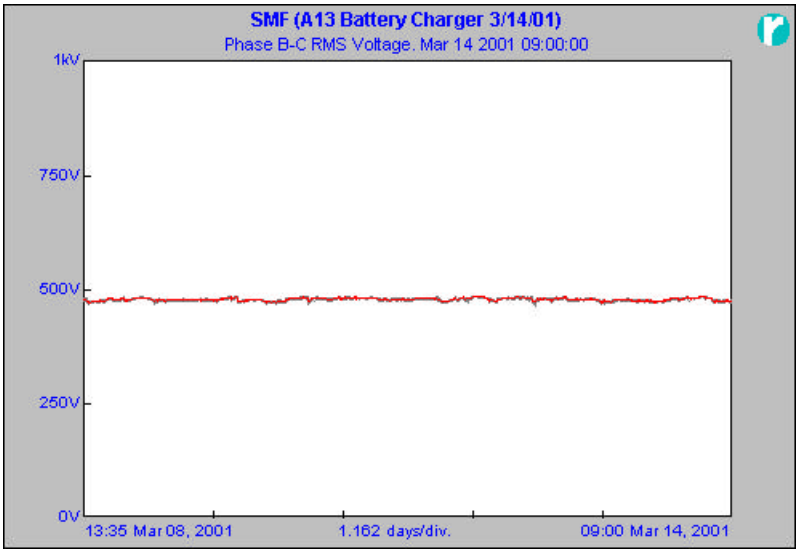
RMS. Voltage Summaries for SMF A13 Battery Charger

Phase A Voltage Summary



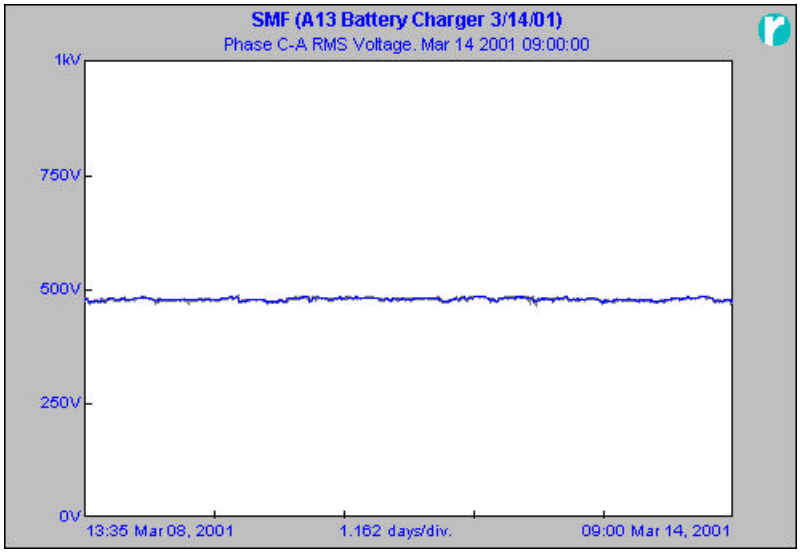
Min.	466.5V	Mar 13 2001 04:55:46
Avg.	**478.7V**	
Max.	485.9V	Mar 09 2001 22:45:46

Phase B Voltage Summary



Min.	466.3V	Mar 12 2001 14:45:46
Avg.	**479.7V**	
Max.	487.0V	Mar 09 2001 22:35:46

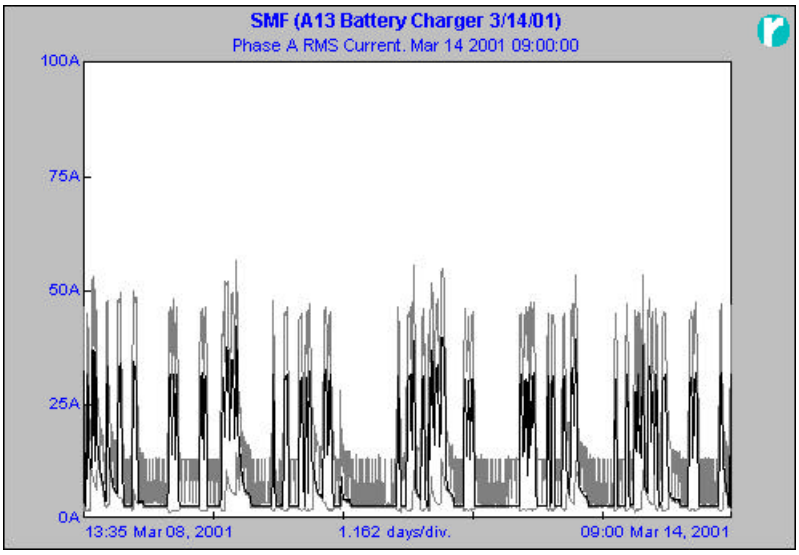
Phase C Voltage Summary



Min.	463.8V	Mar 12 2001 14:45:46
Avg.	**480.2V**	
Max.	487.8V	Mar 09 2001 22:45:46

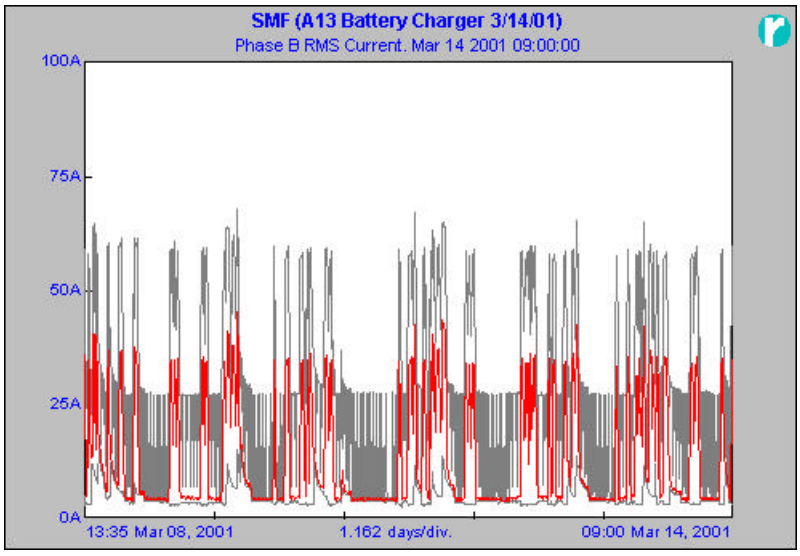
RMS. Current Summaries for SMF A13 Battery Charger

Phase A Current Summary



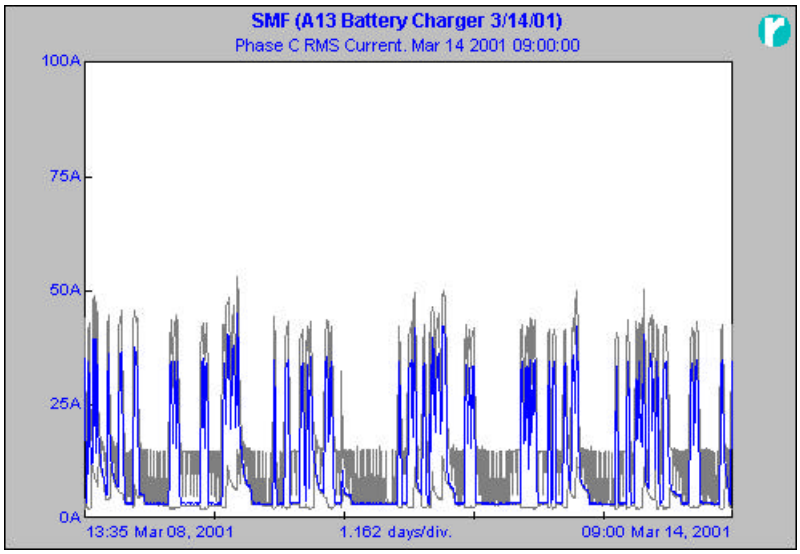
Min.	1.648A	Mar 09 2001 08:05:46
Avg.	**11.03A**	
Max.	56.76A	Mar 09 2001 22:35:46

Phase B Current Summary



Min.	2.563A	Mar 11 2001 09:45:46
Avg.	**13.17A**	
Max.	67.75A	Mar 09 2001 22:35:46

Phase C Current Summary



Min.	2.380A	Mar 08 2001 13:45:46
Avg.	**12.43A**	
Max.	53.10A	Mar 09 2001 22:35:46

Voltage and Current Distortion Summaries

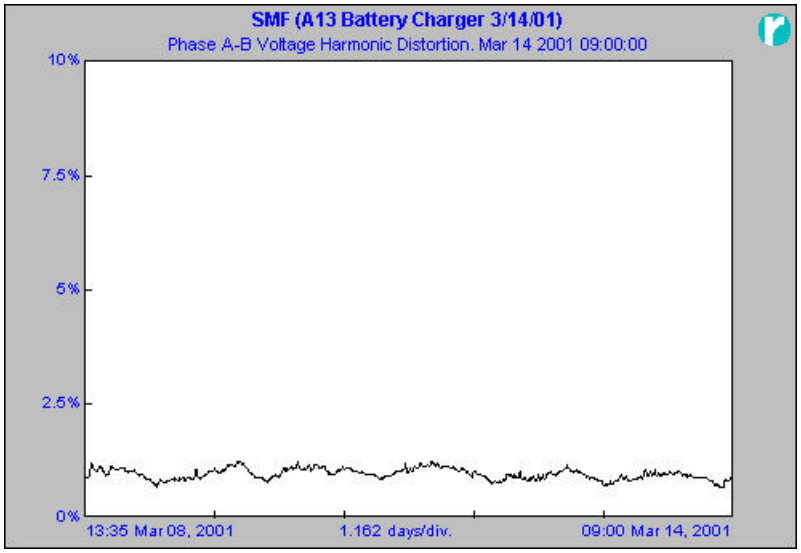
Voltage and Current harmonic distortion measurements for SMFA13 Battery Charger between 13:35:46 on March 8, 2001, through 09:00:00 on March 14, 2001.

Voltage Distortion	Value	Date and Time
Phase A minimum	0.68%	Mar 14 2001 06:05:46
Phase A average	**0.971%**	
Phase A maximum	1.26%	Mar 09 2001 23:15:46
Phase B minimum	0.57%	Mar 13 2001 05:25:46
Phase B average	**0.887%**	
Phase B maximum	1.19%	Mar 10 2001 11:35:46
Phase C minimum	0.64%	Mar 14 2001 06:35:46
Phase C average	**1.014%**	
Phase C maximum	1.35%	Mar 09 2001 23:15:46

Current Distortion	Value	Date and Time
Phase A minimum	15.29%	Mar 13 2001 18:25:46
Phase A average	**133.9%**	
Phase A maximum	327.6%	Mar 09 2001 01:55:46
Phase B minimum	8.68%	Mar 13 2001 18:25:46
Phase B average	**44.18%**	
Phase B maximum	110.5%	Mar 14 2001 07:15:46
Phase C minimum	8.21%	Mar 12 2001 13:15:46
Phase C average	**43.25%**	
Phase C maximum	111.8%	Mar 14 2001 07:15:46

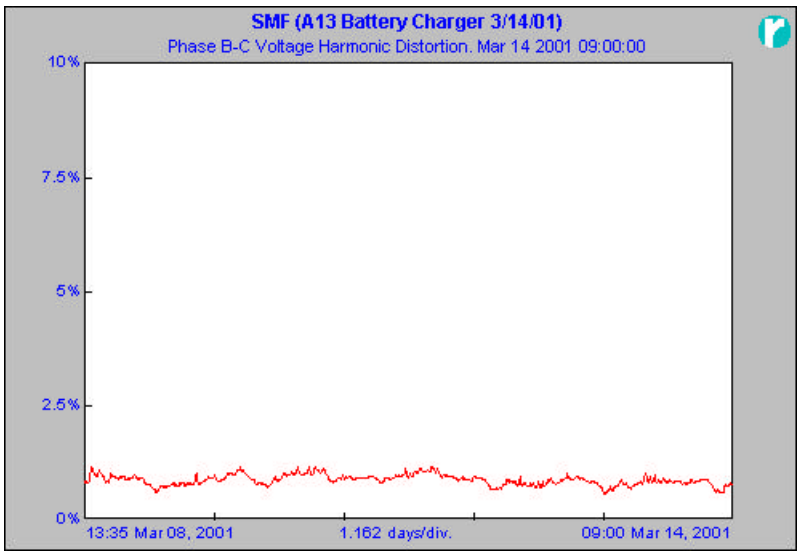
Voltage T.H.D. Summaries for SMF A13 Battery Charger

Phase A Voltage Distortion



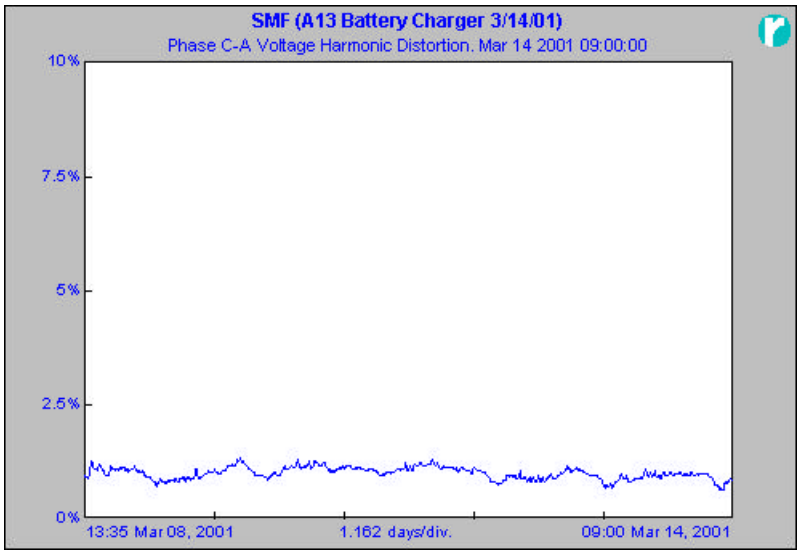
Min.	0.68%	Mar 14 2001 06:05:46
Avg.	**0.971%**	
Max.	1.26%	Mar 09 2001 23:15:46

Phase B Voltage Distortion



Min.	0.57%	Mar 13 2001 05:25:46
Avg.	**0.887%**	
Max.	1.19%	Mar 10 2001 11:35:46

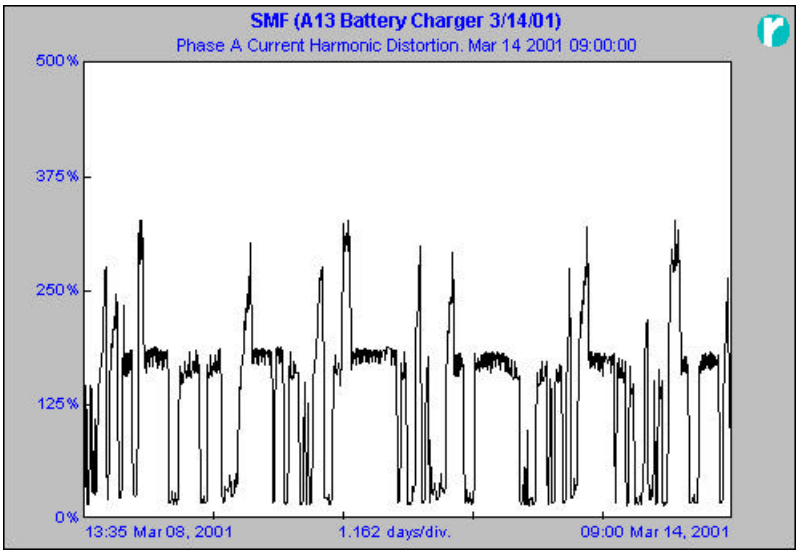
Phase C Voltage Distortion



Min.	0.64%	Mar 14 2001 06:35:46
Avg.	**1.014%**	
Max.	1.35%	Mar 09 2001 23:15:46

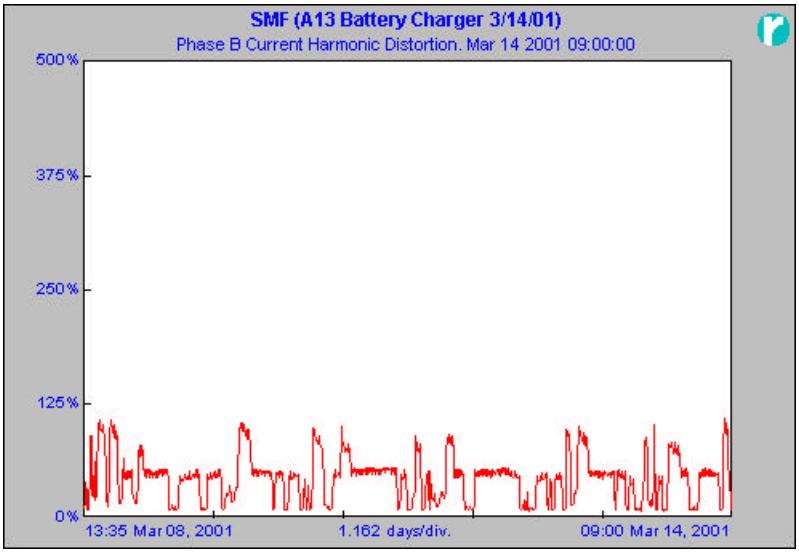
Current T.H.D. Summaries for SMF A13 Battery Charger

Phase A Current Distortion



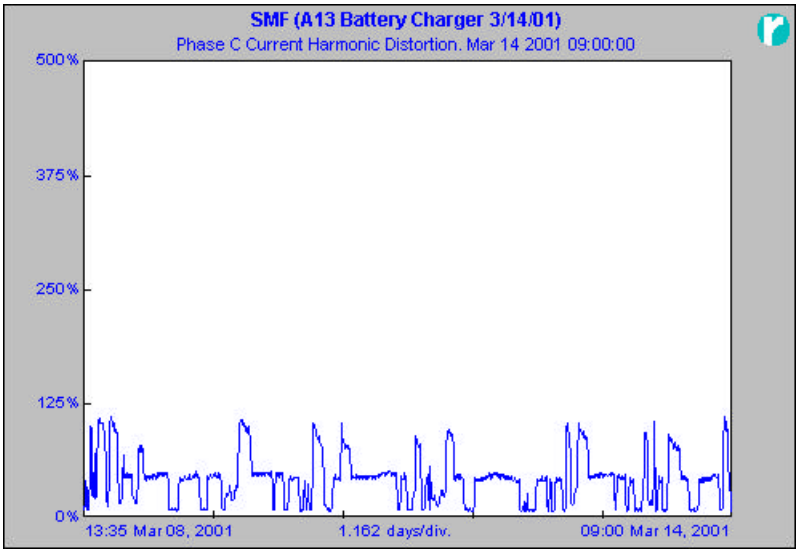
Min.	15.29%	Mar 13 2001 18:25:46
Avg.		**133.9%**
Max.	327.6%	Mar 09 2001 01:55:46

Phase B Current Distortion



Min.	8.68%	Mar 13 2001 18:25:46
Avg.		**44.18%**
Max.	110.5%	Mar 14 2001 07:15:46

Phase C Current Distortion



Min.	8.21%	Mar 12 2001 13:15:46
Avg.		**43.25%**
Max.	111.8%	Mar 14 2001 07:15:46

Power Summaries

Power measurements for SMF A13 Battery Charger from 13:35:46 on March 8, 2001, through 09:00:00 on March 14, 2001.

Imbalance	Value	Date and Time
Minimum Voltage Imbalance	0.08%	Mar 09 2001 12:55:46
Average Voltage Imbalance	**0.167%**	
Maximum Voltage Imbalance	0.31%	Mar 10 2001 20:05:46
Minimum Current Imbalance	4.68%	Mar 11 2001 18:45:46
Average Current Imbalance	**15.52%**	
Maximum Current Imbalance	27.94%	Mar 13 2001 11:25:46

VA Power	Value	Date and Time
Phase A minimum	459.4VA	Mar 11 2001 09:45:46
Phase A average	**3.105kVA**	
Phase A maximum	15.90kVA	Mar 09 2001 22:35:46
Phase B minimum	748.5VA	Mar 11 2001 09:45:46
Phase B average	**3.690kVA**	
Phase B maximum	18.92kVA	Mar 09 2001 22:35:46
Phase C minimum	663.7VA	Mar 08 2001 14:45:46
Phase C average	**3.498kVA**	
Phase C maximum	14.91kVA	Mar 09 2001 22:35:46
Total minimum	2.966kVA	Mar 09 2001 18:05:46
Total average	**10.29kVA**	
Total maximum	37.36kVA	Mar 09 2001 22:35:46

VARS Power	Value	Date and Time
Phase A minimum	-6.977kVAR	Mar 09 2001 22:35:46
Phase A average	**-425.7VAR**	
Phase A maximum	6.803kVAR	Mar 09 2001 22:45:46
Phase B minimum	-8.252kVAR	Mar 10 2001 18:45:46
Phase B average	**-471.1VAR**	
Phase B maximum	8.724kVAR	Mar 12 2001 11:35:46
Phase C minimum	-8.160kVAR	Mar 09 2001 22:35:46
Phase C average	**1.493kVAR**	
Phase C maximum	8.107kVAR	Mar 12 2001 20:45:46
Total minimum	-5.305kVAR	Mar 09 2001 23:05:46
Total average	**596.3VAR**	
Total maximum	7.816kVAR	Mar 09 2001 20:35:46

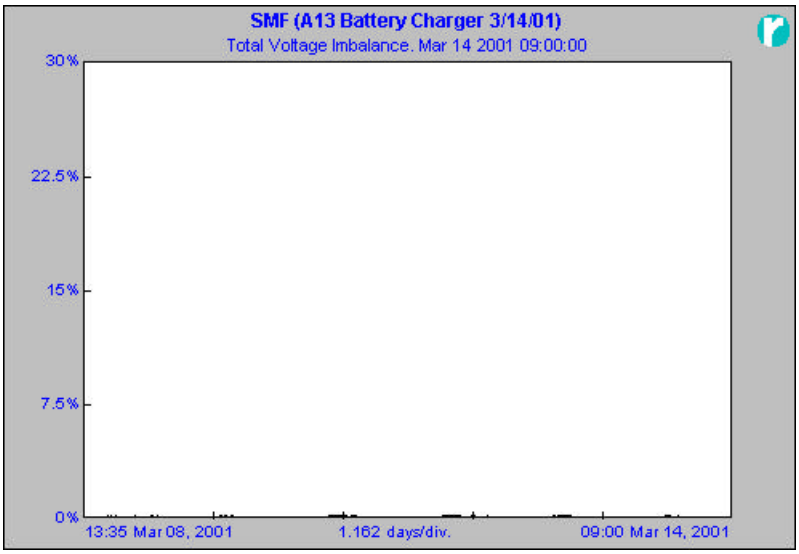
Watts Power	Value	Date and Time
Phase A minimum	-976.6W	Mar 12 2001 18:35:46
Phase A average	**2.256kW**	
Phase A maximum	15.47kW	Mar 09 2001 22:35:46
Phase B minimum	-649.4W	Mar 09 2001 08:25:46
Phase B average	**3.180kW**	
Phase B maximum	17.39kW	Mar 09 2001 22:35:46
Phase C minimum	-1.581kW	Mar 13 2001 12:45:46
Phase C average	**2.970kW**	
Phase C maximum	14.04kW	Mar 09 2001 22:35:46
Total minimum	805.2W	Mar 13 2001 08:35:46
Total average	**8.407kW**	
Total maximum	35.16kW	Mar 09 2001 22:35:46

Demand Power	Value	Date and Time
Phase A minimum	82.57W	Mar 09 2001 11:15:46
Phase A average	**2.440kW**	
Phase A maximum	10.96kW	Mar 09 2001 22:35:46
Phase B minimum	531.5W	Mar 12 2001 06:00:46
Phase B average	**3.180kW**	
Phase B maximum	12.06kW	Mar 09 2001 22:35:46
Phase C minimum	505.9W	Mar 14 2001 08:30:46
Phase C average	**2.970kW**	
Phase C maximum	11.66kW	Mar 09 2001 22:35:46
Total minimum	1.258kW	Mar 14 2001 08:30:46
Total average	**8.591kW**	
Total maximum	34.69kW	Mar 09 2001 22:35:46

Power Factor	Value	Date and Time
Phase A minimum	0.000 Lead	Mar 09 2001 19:55:46
Phase A average	**0.508 Lead**	
Phase A maximum	0.000 Lag	Mar 10 2001 12:05:46
Phase B minimum	0.000 Lead	Mar 12 2001 18:35:46
Phase B average	**0.694 Lead**	
Phase B maximum	0.000 Lag	Mar 10 2001 17:55:46
Phase C minimum	0.000 Lead	Mar 13 2001 08:05:46
Phase C average	**0.676 Lag**	
Phase C maximum	0.000 Lag	Mar 12 2001 20:55:46
Total minimum	0.970	Mar 10 2001 06:25:46
Total average	**0.580**	
Total maximum	0.264	Mar 12 2001 08:55:46

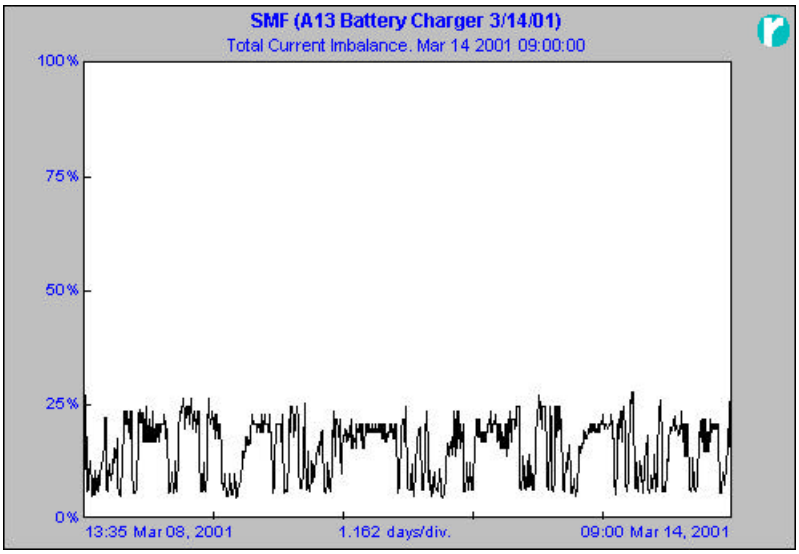
Voltage and Current Imbalance Summaries for SMF A13 Battery Charger

Voltage Imbalance



Minimum Voltage Imbalance	0.08%	Mar 09 2001 12:55:46
Average Voltage Imbalance	**0.167%**	
Maximum Voltage Imbalance	0.31%	Mar 10 2001 20:05:46

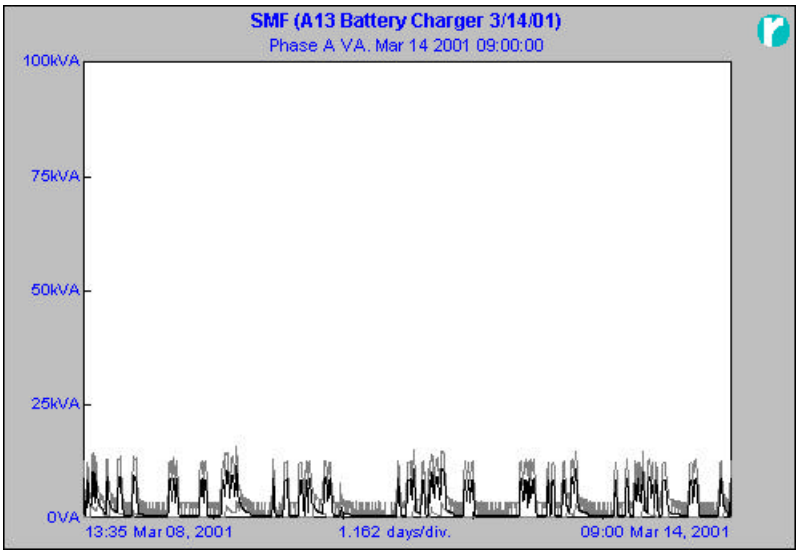
Current Imbalance



Minimum Current Imbalance	4.68%	Mar 11 2001 18:45:46
Average Current Imbalance	**15.52%**	
Maximum Current Imbalance	27.94%	Mar 13 2001 11:25:46

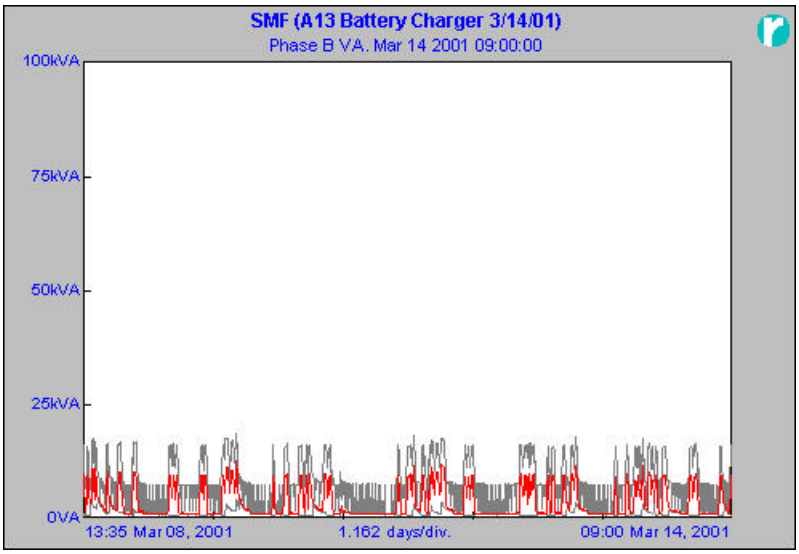
VA Power Summaries for SMF A13 Battery Charger

Phase A VA Summary



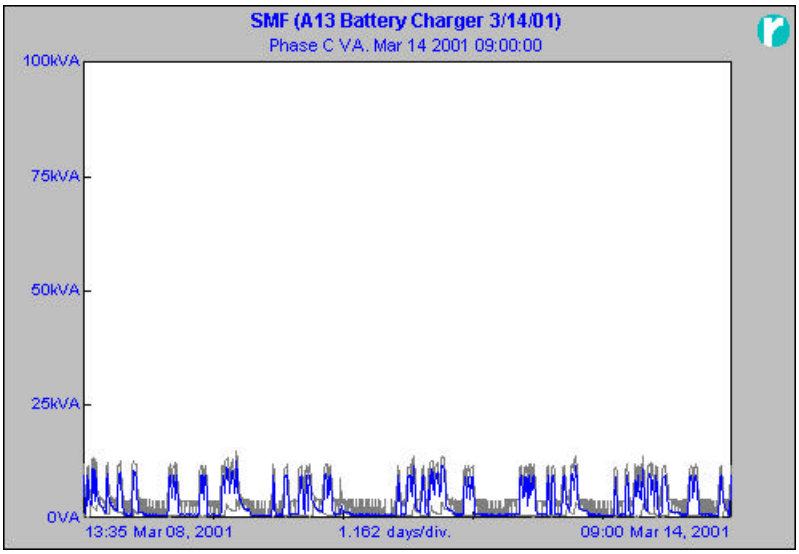
Min.	459.4VA	Mar 11 2001 09:45:46
Avg.	**3.105kVA**	
Max.	15.90kVA	Mar 09 2001 22:35:46

Phase B VA Summary



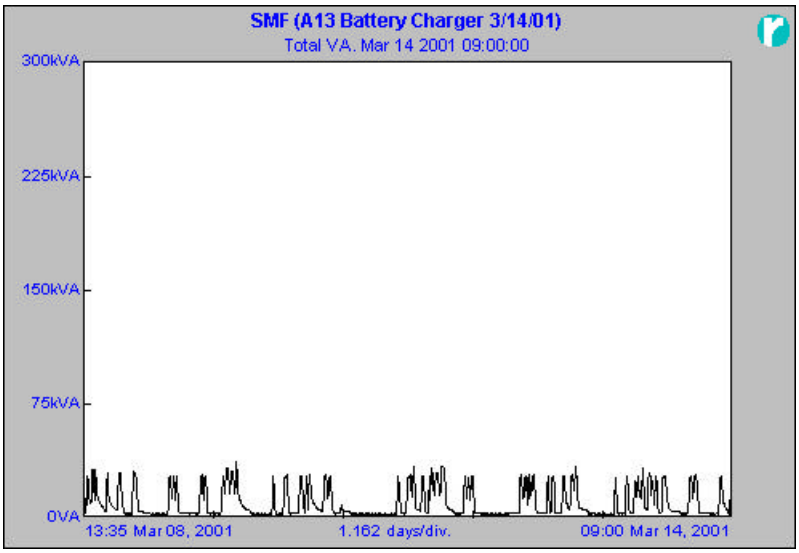
Min.	748.5VA	Mar 11 2001 09:45:46
Avg.	**3.690kVA**	
Max.	18.92kVA	Mar 09 2001 22:35:46

Phase C VA Summary



Min.	663.7VA	Mar 08 2001 14:45:46
Avg.	**3.498kVA**	
Max.	14.91kVA	Mar 09 2001 22:35:46

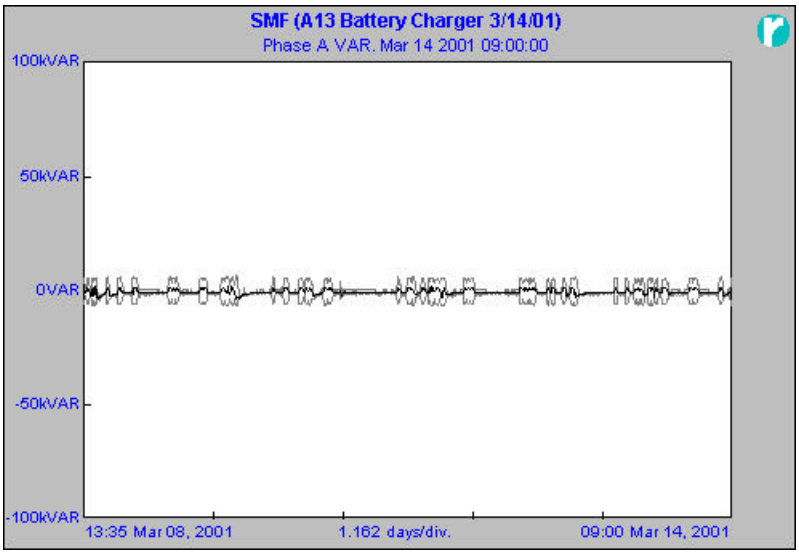
Total VA Summary



Min.	2.966kVA	Mar 09 2001 18:05:46
Avg.	**10.29kVA**	
Max.	37.36kVA	Mar 09 2001 22:35:46

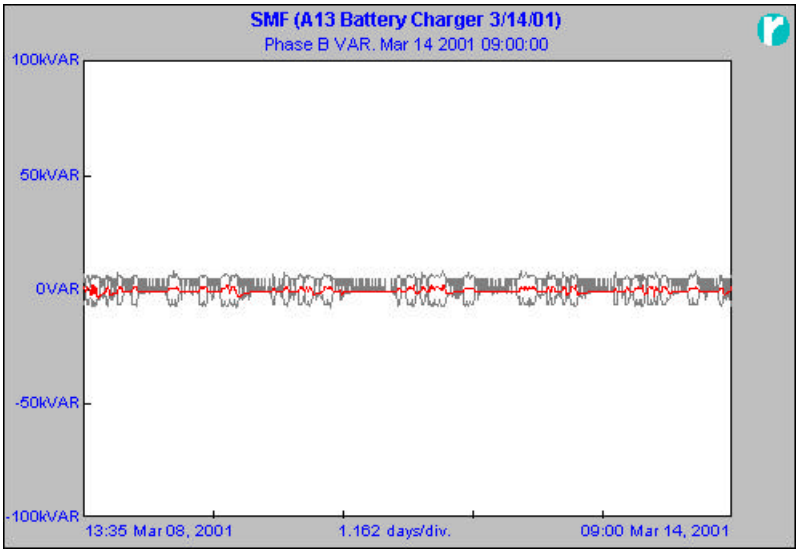
VARS Power Summaries for SMF A13 Battery Charger

Phase A VARS Summary



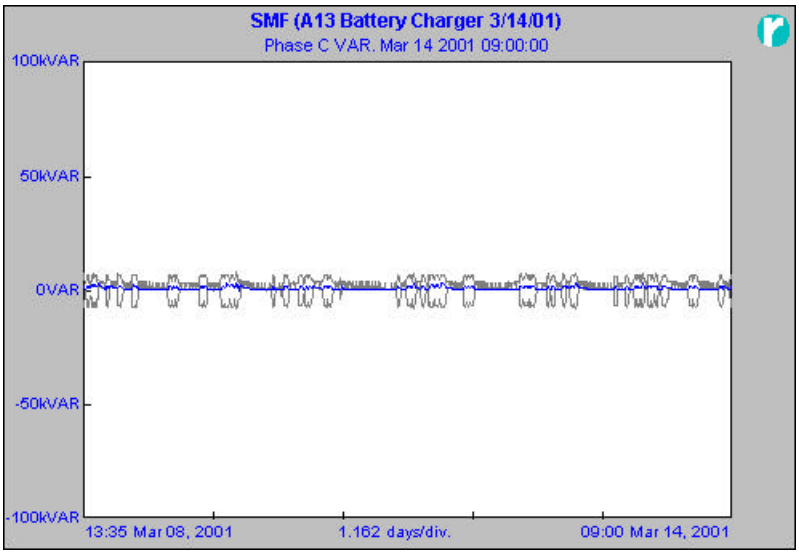
Min.	-6.977kVAR	Mar 09 2001 22:35:46
Avg.	**-425.7VAR**	
Max.	6.803kVAR	Mar 09 2001 22:45:46

Phase B VARS Summary



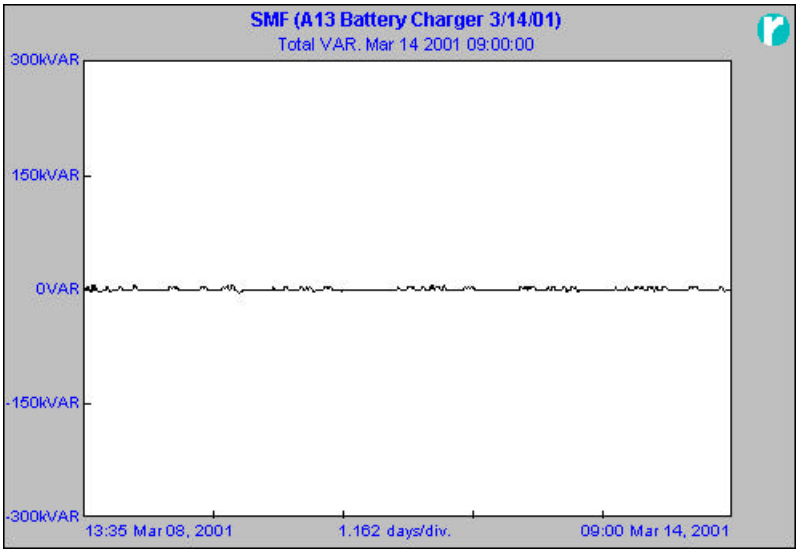
Min.	-8.252kVAR	Mar 10 2001 18:45:46
Avg.	**-471.1VAR**	
Max.	8.724kVAR	Mar 12 2001 11:35:46

Phase C VARS Summary



Min.	-8.160kVAR	Mar 09 2001 22:35:46
Avg.	**1.493kVAR**	
Max.	8.107kVAR	Mar 12 2001 20:45:46

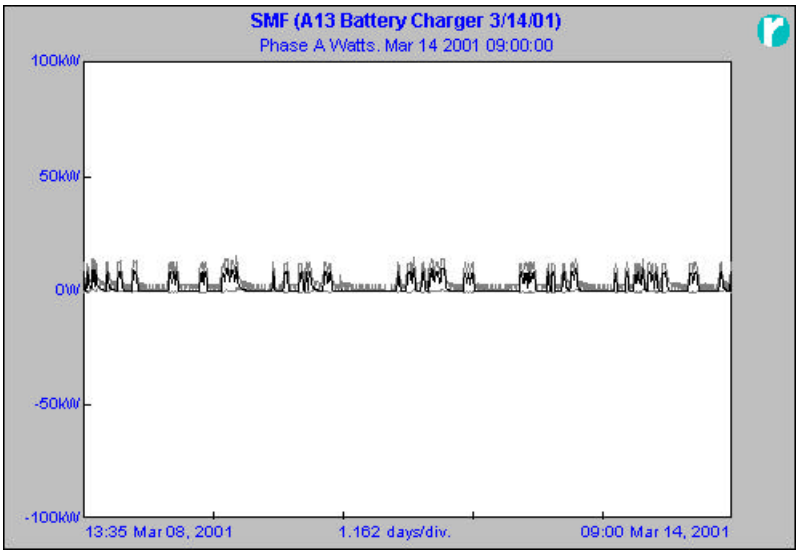
Total VARS Summary



Min.	-5.305kVAR	Mar 09 2001 23:05:46
Avg.	**596.3 VAR**	
Max.	7.816kVAR	Mar 09 2001 20:35:46

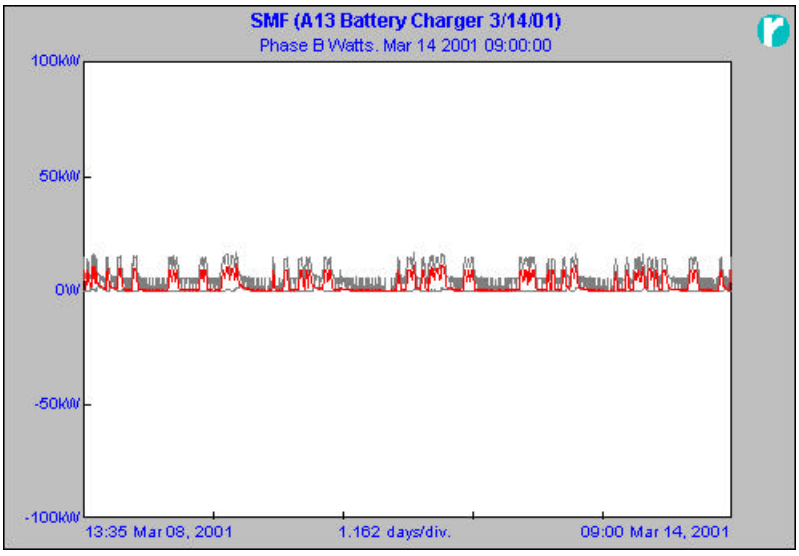
WATTS Power Summaries for SMF A13 Battery Charger

Phase A Watts Summary



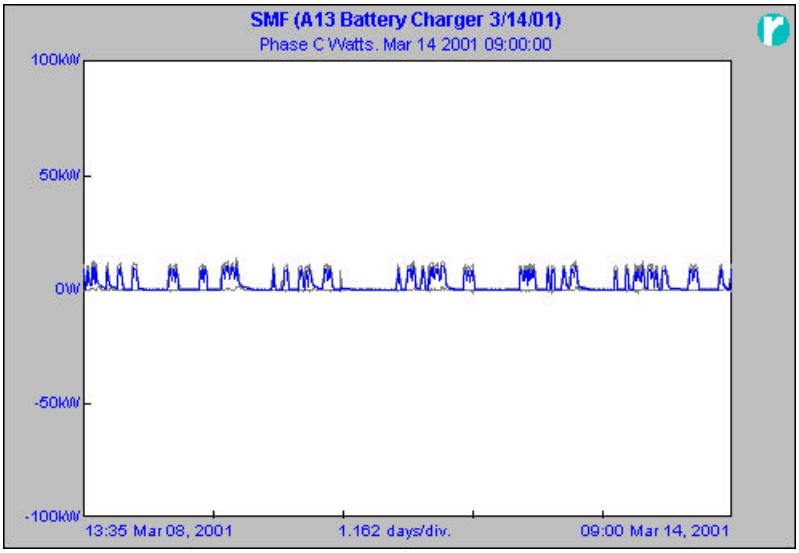
Min.	-976.6W	Mar 12 2001 18:35:46
Avg.	**2.256kW**	
Max.	15.47kW	Mar 09 2001 22:35:46

Phase B Watts Summary



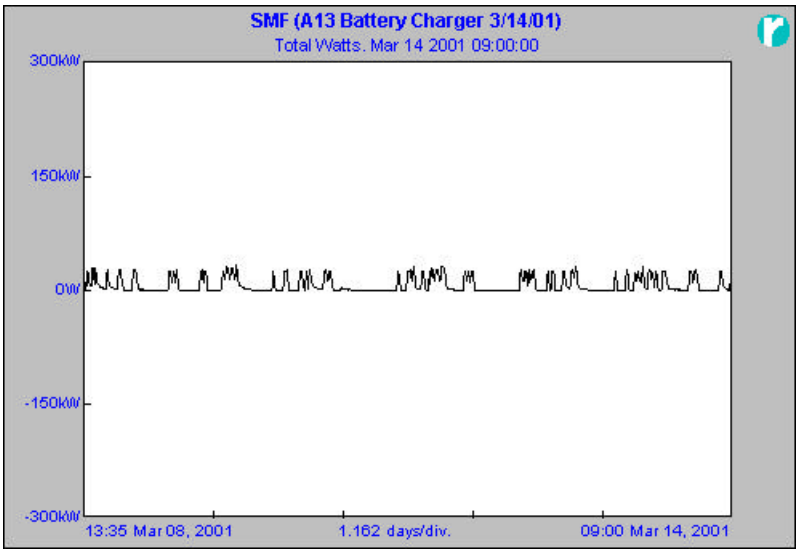
Min.	-649.4W	Mar 09 2001 08:25:46
Avg.	**3.180kW**	
Max.	17.39kW	Mar 09 2001 22:35:46

Phase C Watts Summary



Min.	-1.581kW	Mar 13 2001 12:45:46
Avg.	**2.970kW**	
Max.	14.04kW	Mar 09 2001 22:35:46

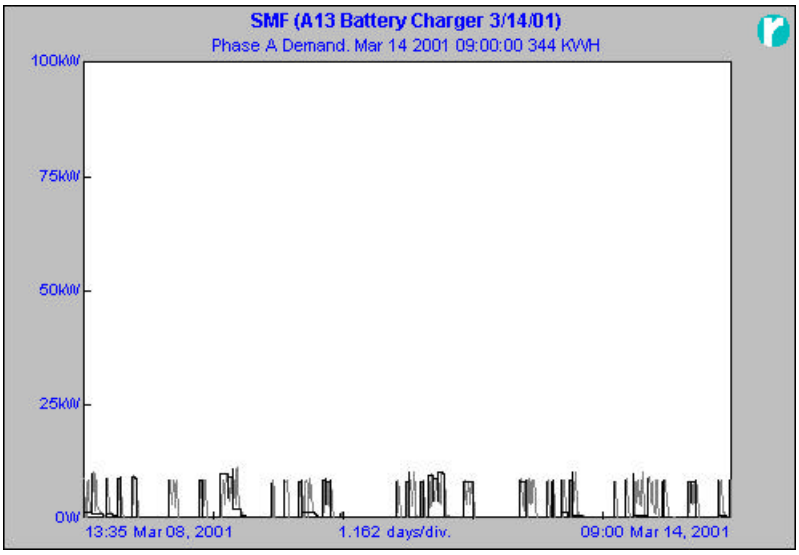
Total Watts Summary



Min.	805.2W	Mar 13 2001 08:35:46
Avg.	**8.407kW**	
Max.	35.16kW	Mar 09 2001 22:35:46

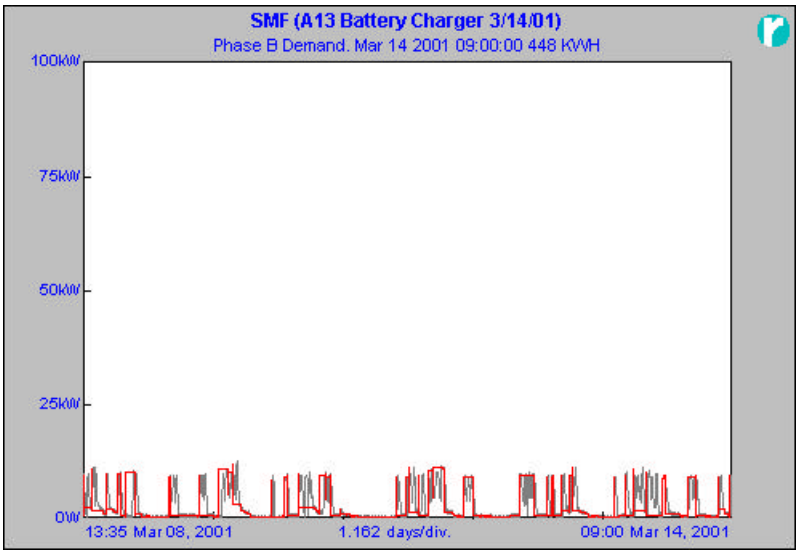
Demand Power Summaries for SMF A13 Battery Charger

Phase A Demand Summary



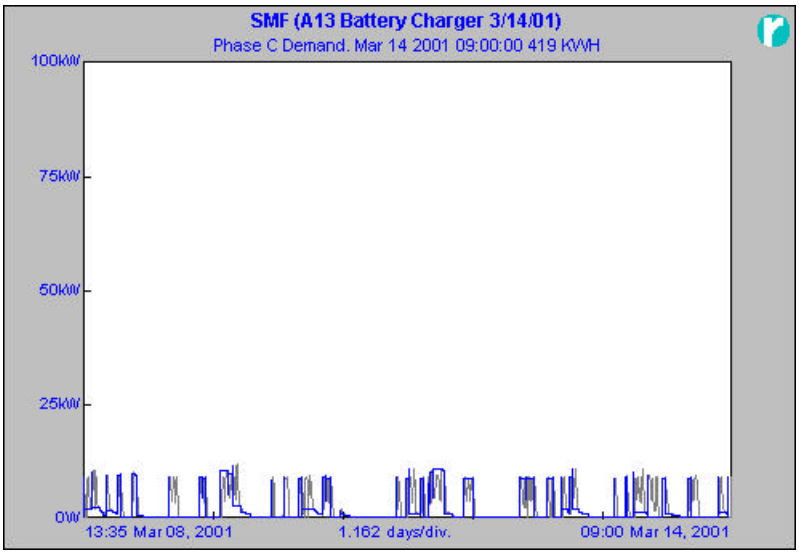
Min.	82.57W	Mar 09 2001 11:15:46
Avg.	**2.440kW**	
Max.	10.96kW	Mar 09 2001 22:35:46

Phase B Demand Summary



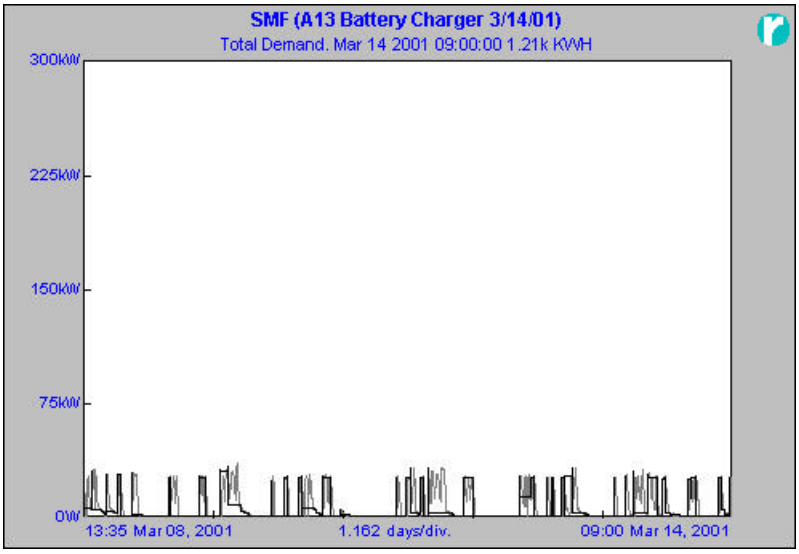
Min.	531.5W	Mar 12 2001 06:00:46
Avg.	**3.180kW**	
Max.	12.06kW	Mar 09 2001 22:35:46

Phase C Demand Summary



Min.	505.9W	Mar 14 2001 08:30:46
Avg.	**2.970kW**	
Max.	11.66kW	Mar 09 2001 22:35:46

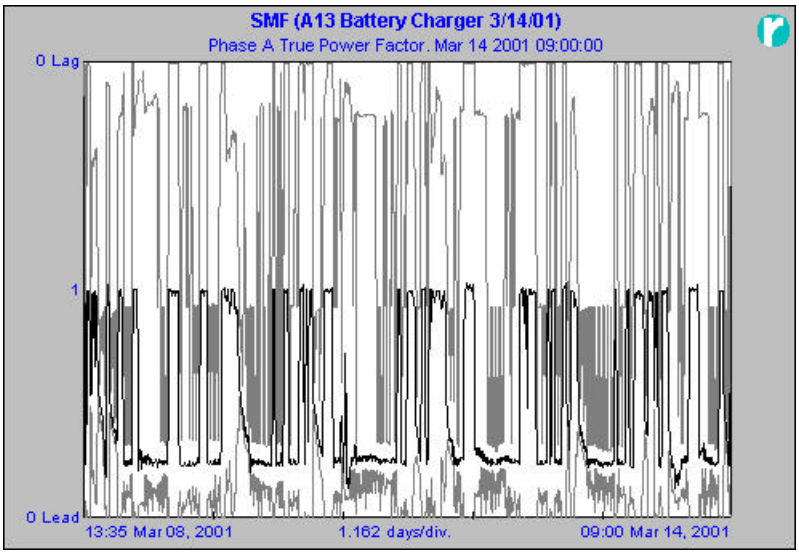
Total Demand Summary



Min.	1.258kW	Mar 14 2001 08:30:46
Avg.	**8.591kW**	
Max.	34.69kW	Mar 09 2001 22:35:46

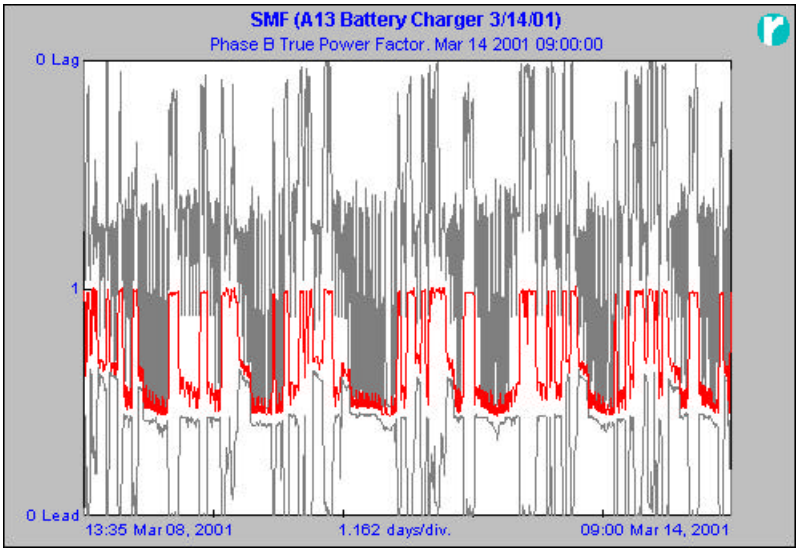
Power Factor Summaries for SMF A13 Battery Charger

Phase A Power Factor Summary



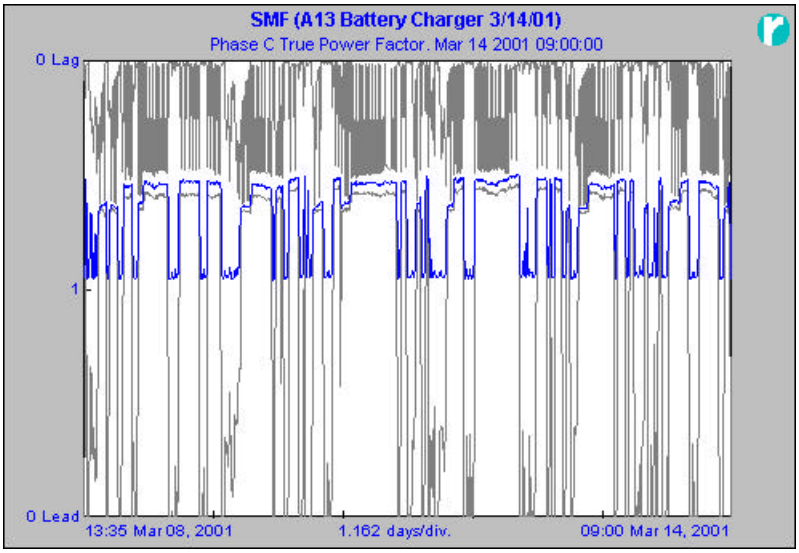
Min.	0.000 Lead	Mar 09 2001 19:55:46
Avg.	**0.508 Lead**	
Max.	0.000 Lag	Mar 10 2001 12:05:46

Phase B Power Factor Summary



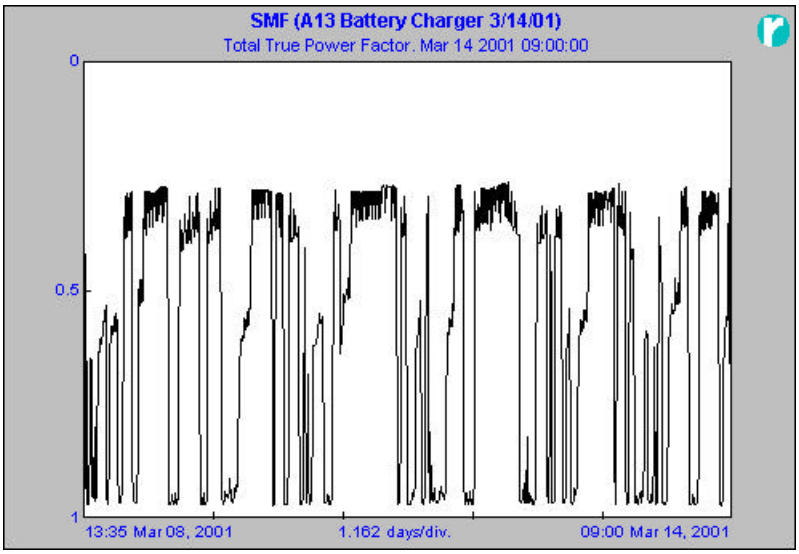
Min.	0.000 Lead	Mar 12 2001 18:35:46
Avg.	**0.694 Lead**	
Max.	0.000 Lag	Mar 10 2001 17:55:46

Phase C Power Factor Summary



Min.	0.000 Lead	Mar 13 2001 08:05:46
Avg.	**0.676 Lag**	
Max.	0.000 Lag	Mar 12 2001 20:55:46

Total Power Factor Summary



Min.	0.970	Mar 10 2001 06:25:46
Avg.	**0.580**	
Max.	0.264	Mar 12 2001 08:55:46

Power Analysis A4 1EMCCG2 A13 Total Panel Load - ETEC Charger - 12 Hour Monitoring

Introduction

This is a summary of the power conditions at the SMF site, as recorded at location Panel 1EMCCG2 Gate A13. Data at this location was collected from 03/14/01 09:46:03 through 03/14/01 21:46:03.

This summary is composed of:

- The initial conditions section, which defines the baseline power conditions at the above location**.**
- The Events section, which is a summary of the voltage events that occurred at this location during the monitoring interval. Events are defined as changes in the monitored voltage. These changes may be subtle or severe. The power tolerance curve provides a graphical representation of the likelihood of an event being capable of disrupting equipment operations.
- The Voltage Current and Frequency (VIF) section, which contains summaries for each of these parameters during the monitor interval.
- The Harmonics section, which contains the voltage and current harmonics, and harmonic distortion summaries acquired during the monitor interval.
- The Power section. This contains the VA, VARS, Watts, and Power factor acquired during the monitor interval. For multiphase locations, voltage and current imbalance are also included.

Site and Location Information

Site Information

Name	SMF
Account Number	Southwest A13
Date and Time	08/30/00 10:40:53

Location Information

Name	1EMCCG2 A13 Panel Total
Power Type	Three phase wye
Feed Phase	277/480V
Date and Time	03/20/01 10:18:09
Nominal Frequency	60 Hz

Report Parameters

This report was prepared on 03/20/01 by Power Quality of SMUD. The following limits were used in analyzing the results.

Maximum Phase Voltage.	295 V
Minimum Phase Voltage.	260 V
Maximum Neutral Voltage.	2 V
Maximum Impulse Voltage.	330 V
Maximum. Waveshape Voltage.	10 V
Maximum Frequency Deviation.	0.02 Hz
Minimum Power Factor.	0.8
Maximum Voltage T.H.D.	5 %
Maximum Current T.H.D	200 %
Maximum Voltage Imbalance.	2 %
Maximum Current Imbalance.	20 %

Any values outside these limits are noted in the report. Values within the limits are considered to be within a safe operating range.

Initial Conditions

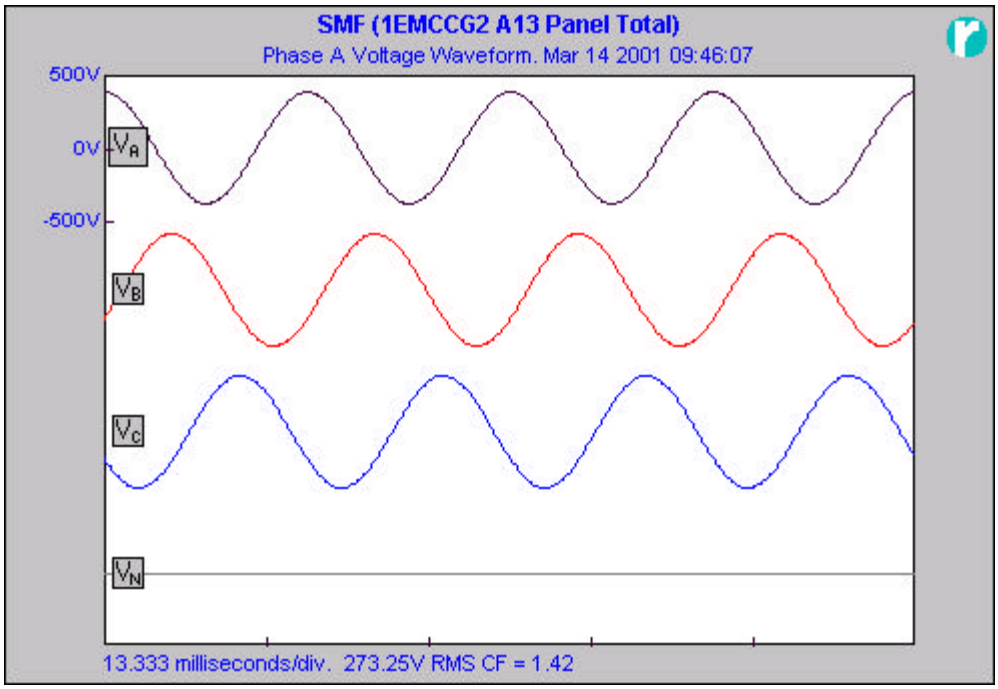
A summary of all the electrical parameters at this location is presented in the tables and graphs below. Parameters marked with an '*' lie outside the limits defined above.

Initial Power measurements for SMF MCC 1EMCCG2 A13 Panel Total, 03/20/01 at 10:18:09

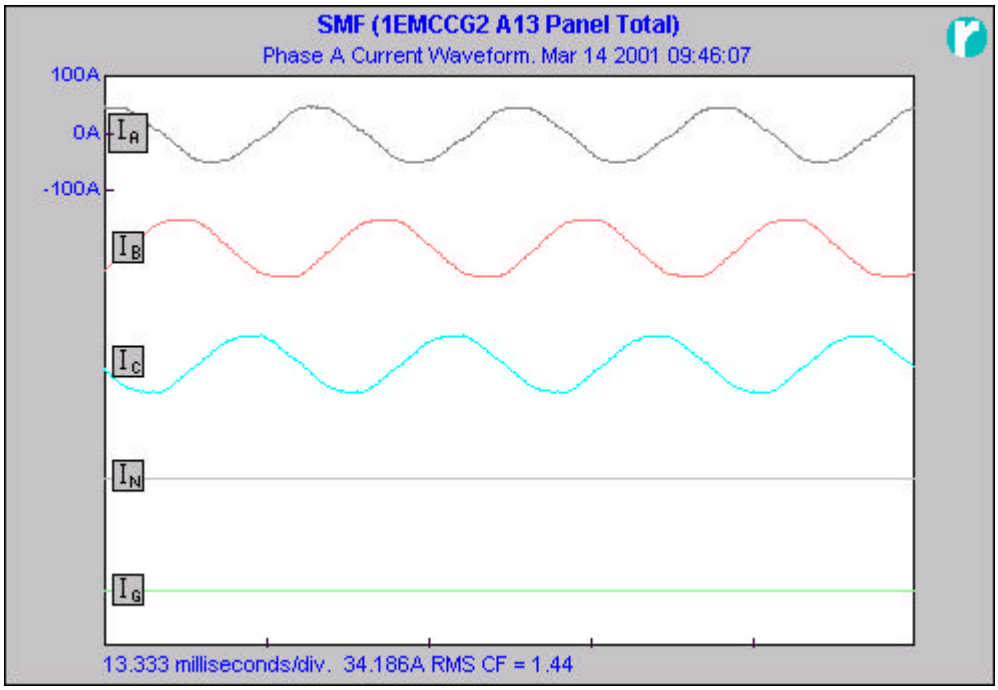
Measurement	Phase A	Phase B	Phase C	Neutral	Ground
True RMS. Voltage	273.2V	275.6V	275.0V	83.02mV	
Max. Peak to Peak Voltage	778.1V	782.6V	782.5V		
True RMS. Current	34.18A	36.81A	35.51A	942.1mA	63.85mA
Max. Peak to Peak Current	97.41A	100.7A	100.1A		
Fundamental RMS. Voltage	273.2V	275.5V	275.0V		
Voltage Angle	0°	240.1°	119.9°		
Fundamental RMS. Current	34.14A	36.92A	35.45A		
Current Angle	346.4°	226.2°	102.7°		
Fundamental Impedance	8.002 Ohms	7.463 Ohms	7.757 Ohms		
Impedance Angle	13.50°	13.92°	17.16°		
Voltage Imbalance	0.50%				
Current Imbalance	3.99%				
Total Voltage Harmonics	0.966%	0.862%	0.886%	93.60%	
Total Current Harmonics	5.397%	4.192%	4.417%	585.8%	
True VA	9.305k	10.14k	9.770k	0.070	
True VARS.	1.910k	2.116k	2.791k	0	
True Watts	9.107k	9.917k	9.363k	-0.070	
Distortion	37.65	41.47	47.13	-0.071	
True Power Factor	0.978	0.978	0.958	1	
Fundamental VA	9.327k	10.17k	9.750k	0.000	
Fundamental VARS.	2.178k	2.448k	2.876k	-0	
Fundamental Watts	9.069k	9.876k	9.316k	0.000	
Fundamental Power Factor	0.972	0.970	0.955	-0.981	

The Initial Conditions are within the limits defined above.

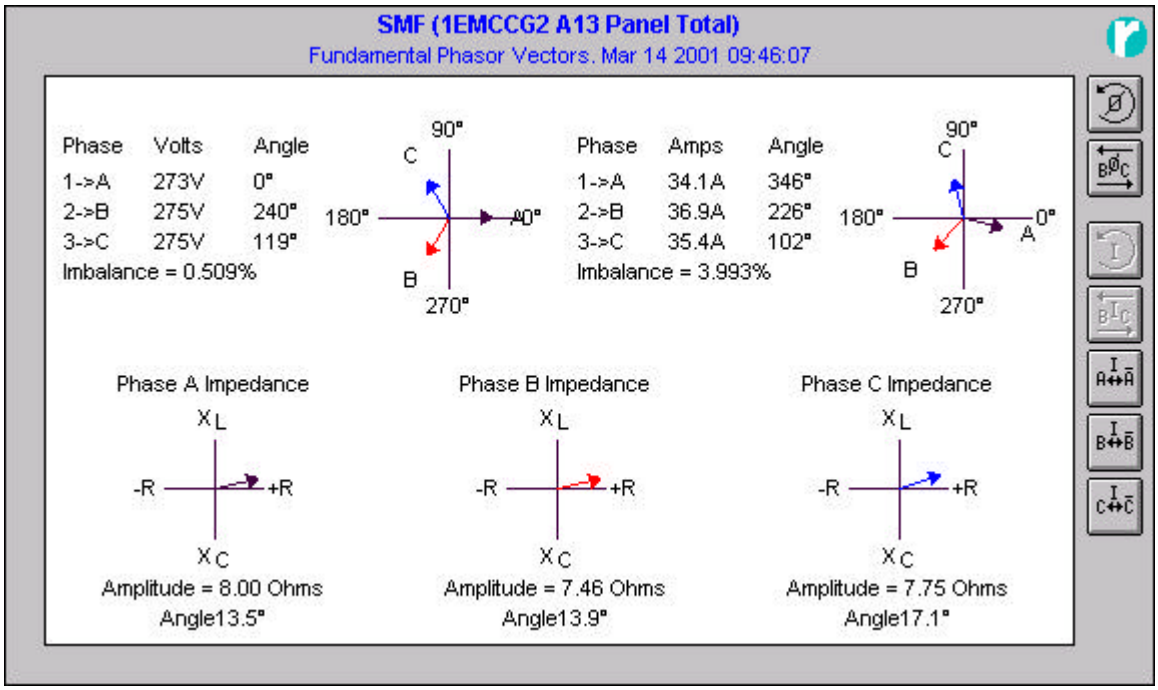
The Voltage waveforms for SMF MCC 1EMCCG2 A13 Panel Total are shown below:



The Current waveforms for SMF MCC 1EMCCG2 A13 Panel Total are shown below:



The Voltage, Current and Impedance Phasors for SMF MCC 1EMCCG2 A13 Panel Total are shown below:



Voltage Events

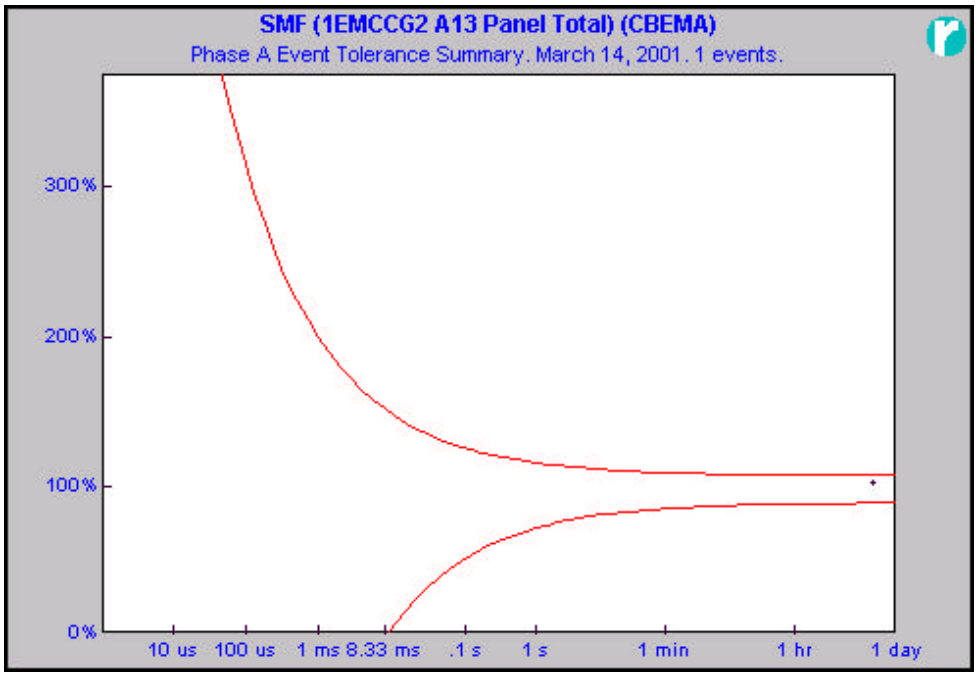
The following summarizes the results of the Power Quality monitoring survey from 03/14/01 09:46:03 through 03/14/01 21:46:03. It is intended to present an overview of the power quality at SMF MCC 1EMCCG2 A13 Panel Total. The table below is a listing of the most significant events.

Event Description	No.	Amp.	Duration	Date and Time
Phase A Largest RMS. Event	0	281.6V	11.999 hr	Mar 14 2001 09:46:06
Phase A Largest Waveshape Event	N/A			
Phase A Longest Waveshape Event	N/A			
Phase A Largest Impulse Event	N/A			
Phase A Longest Impulse Event	N/A			
Phase B Largest RMS. Event	1	284.3V	11.999 hr	Mar 14 2001 09:46:06
Phase B Largest Waveshape Event	N/A			
Phase B Longest Waveshape Event	N/A			
Phase B Largest Impulse Event	N/A			
Phase B Longest Impulse Event	N/A			
Phase C Largest RMS. Event	2	283.5V	11.999 hr	Mar 14 2001 09:46:06
Phase C Largest Waveshape Event	N/A			
Phase C Longest Waveshape Event	N/A			
Phase C Largest Impulse Event	N/A			
Phase C Longest Impulse Event	N/A			
Neutral Largest RMS. Event	3	158.7mV	11.999 hr	Mar 14 2001 09:46:06
Neutral Largest Waveshape Event	N/A			
Neutral Longest Waveshape Event	N/A			
Neutral Largest Impulse Event	N/A			
Neutral Longest Impulse Event	N/A			

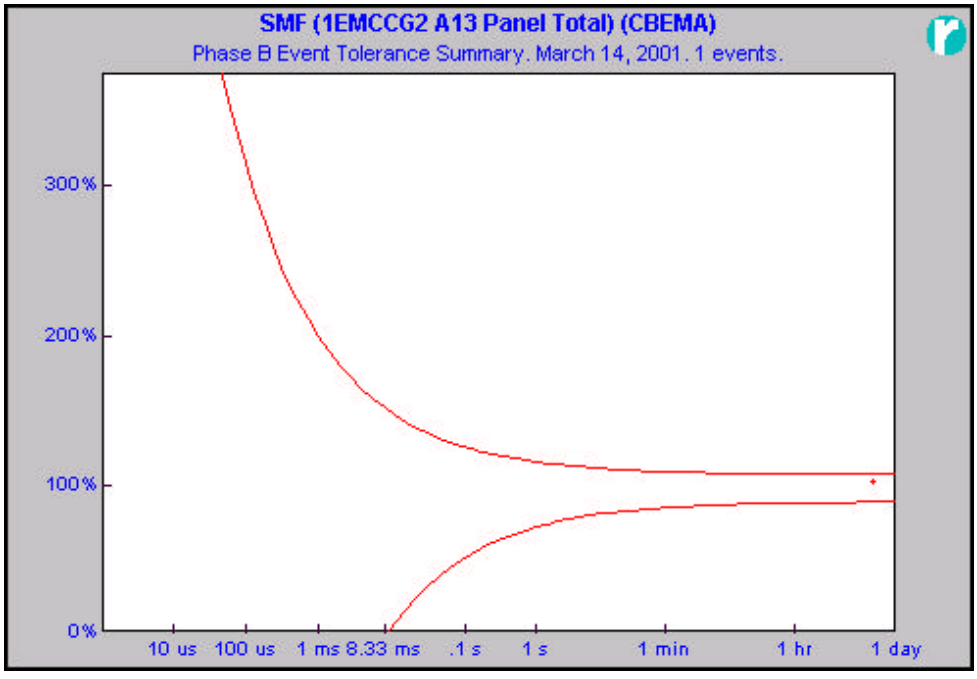
Power Tolerance Envelope

The power quality parameters are summarized in the Power Tolerance Envelope shown below. Each dot on these graphs represents an event. The areas outside of these lines depict events which are often associated with equipment malfunction. **No significant events were recorded during the monitoring period.**

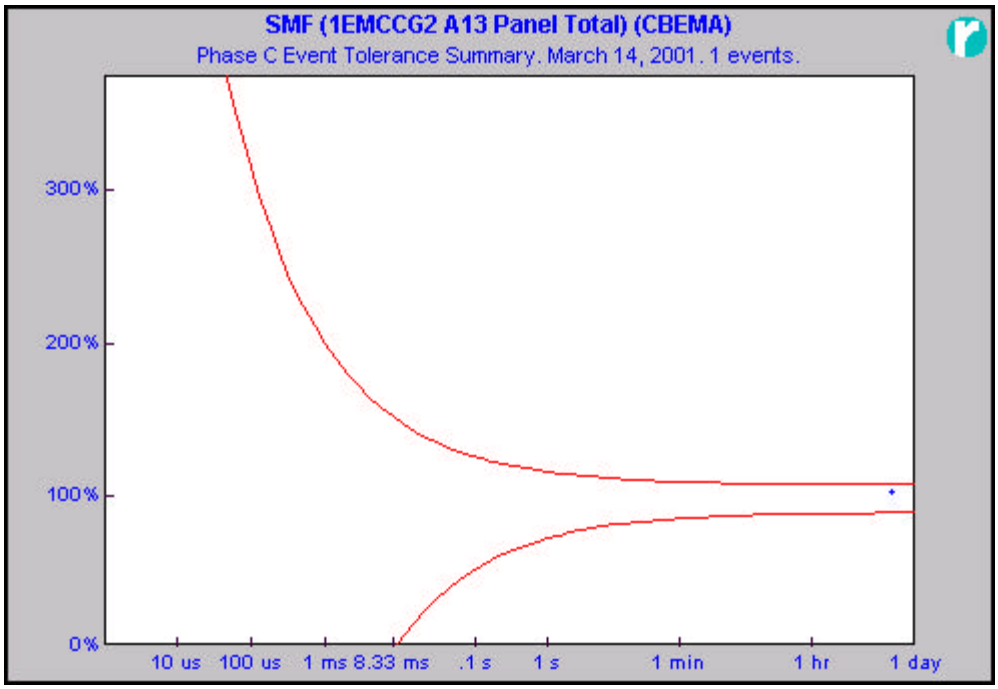
Phase A Event Tolerance Summary



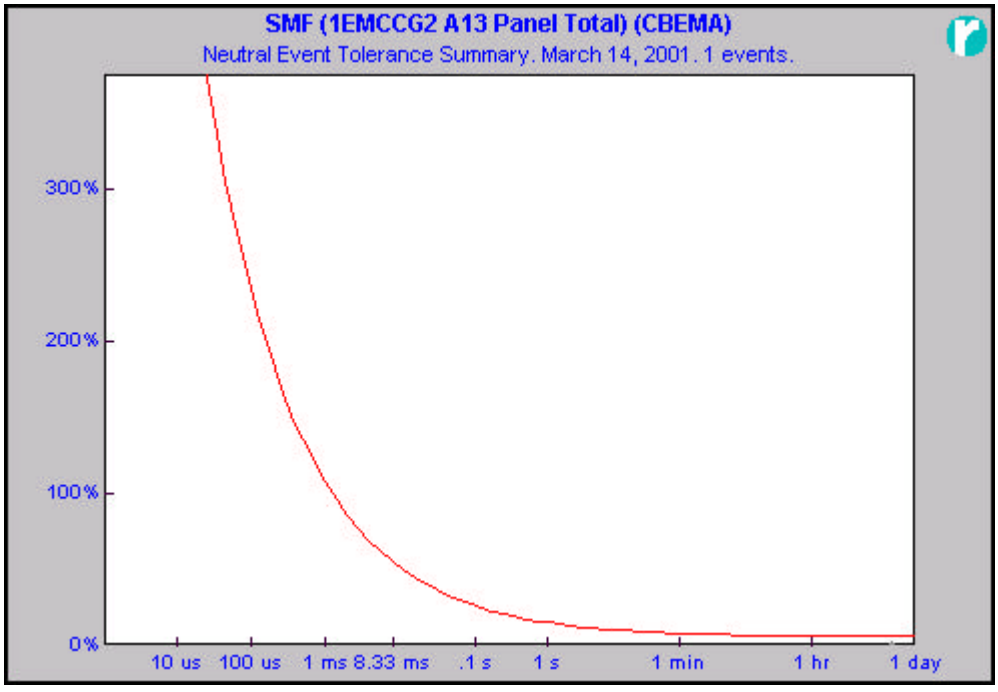
Phase B Event Tolerance Summary



Phase C Event Tolerance Summary



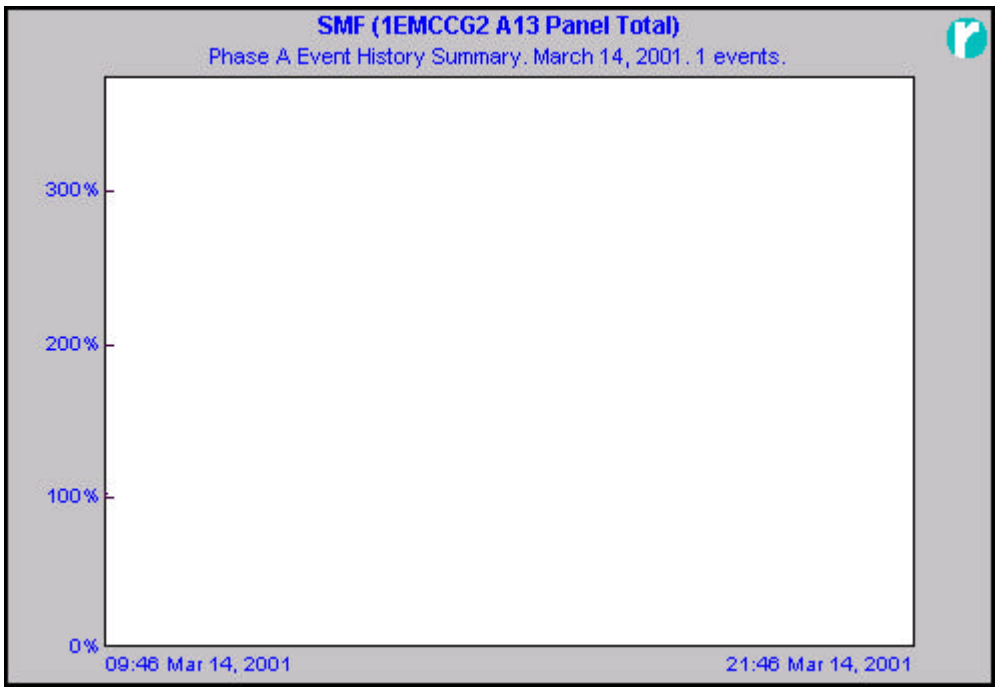
Neutral Event Tolerance Summary



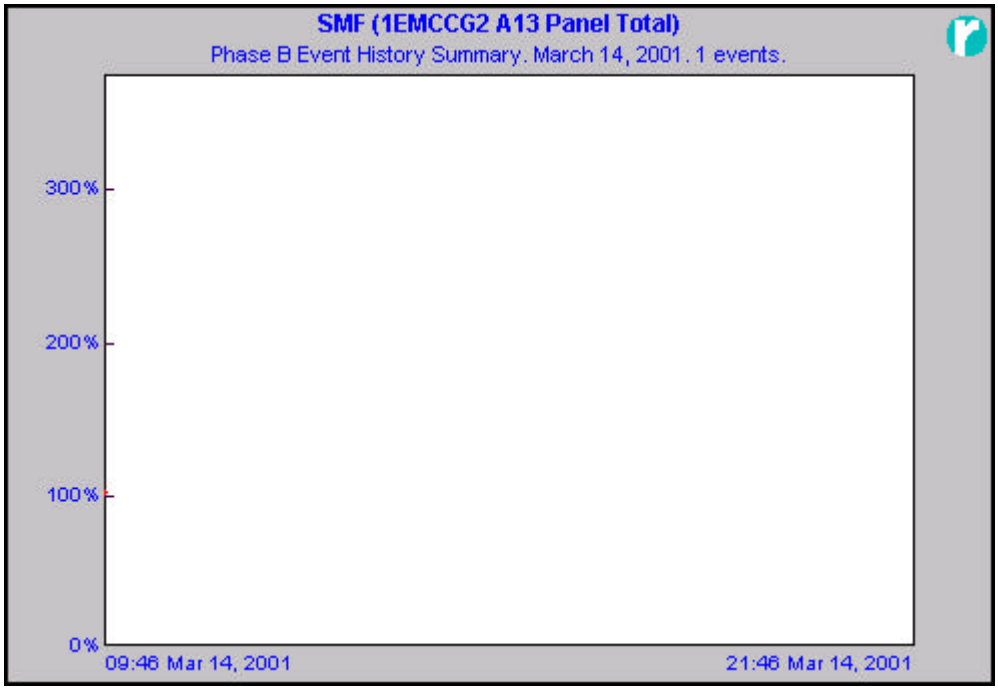
Event History Graphs

A summary of events that occurred during the monitoring interval is shown in the event history graphs below. These events are graphed by amplitude versus time of occurrence. **No significant events were recorded during the monitoring period.**

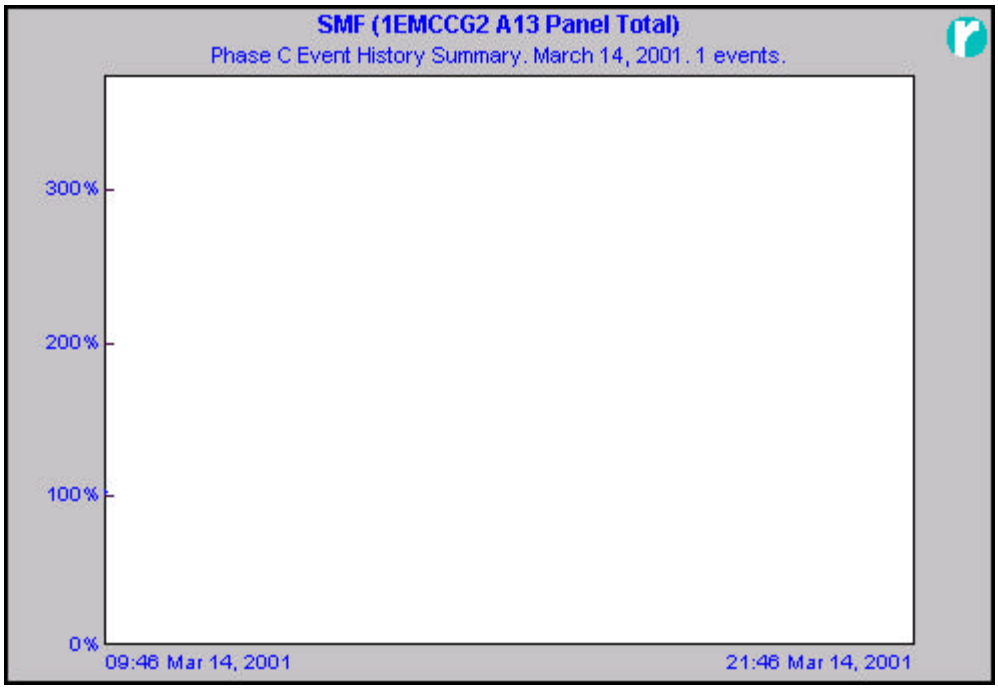
Phase A Event History Summary



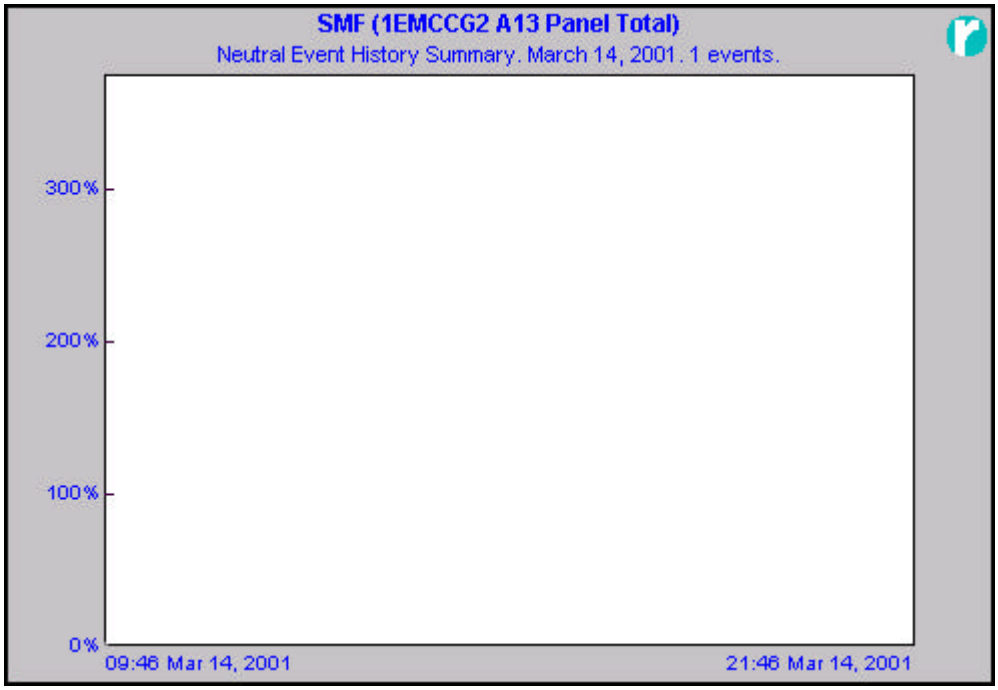
Phase B Event History Summary



Phase C Event History Summary



Neutral Event History Summary



Impulses

Impulses are shown on the left side of the Power Tolerance Envelope. They are relatively high frequency voltage excursions of short duration. When of significant magnitude and duration, these disturbances can cause malfunction of sensitive electronic equipment and damage both components and insulation. **No significant impulses occurred during the monitoring period.**

Waveshape Faults

Waveshape faults are longer in duration than impulses and are shown in the middle of the Power Tolerance Envelope. They are often sub-cycle distortions of the AC sinusoid. However these distortions can last for a fraction of the single cycle period or they can continue for hundreds of milliseconds, hours or even days. All equipment which is not supplied by an Uninterruptible Power Supply, or whose power supply doesn't inherently have sufficient "ride through" to withstand the disturbance will be disrupted. Frequently these disturbances are associated with impulses. **No significant Waveshape Faults occurred during the monitoring period.**

Voltage Swells and Sags

The utility strives to keep RMS levels within a +5%, -5% range of the nominal voltage. Swells are those RMS levels which rise above the +5% range. Sags are those RMS levels which go below the -5% range. The duration is generally from a few cycles to a few seconds. **No significant RMS events occurred during the monitoring period**.

Voltage, Current and Frequency Summaries

Voltage, Current and Frequency measurements for SMF MCC 1EMCCG2 A13 Panel
Total from 03/14/01 09:46:03 through 03/14/01 21:46:03.

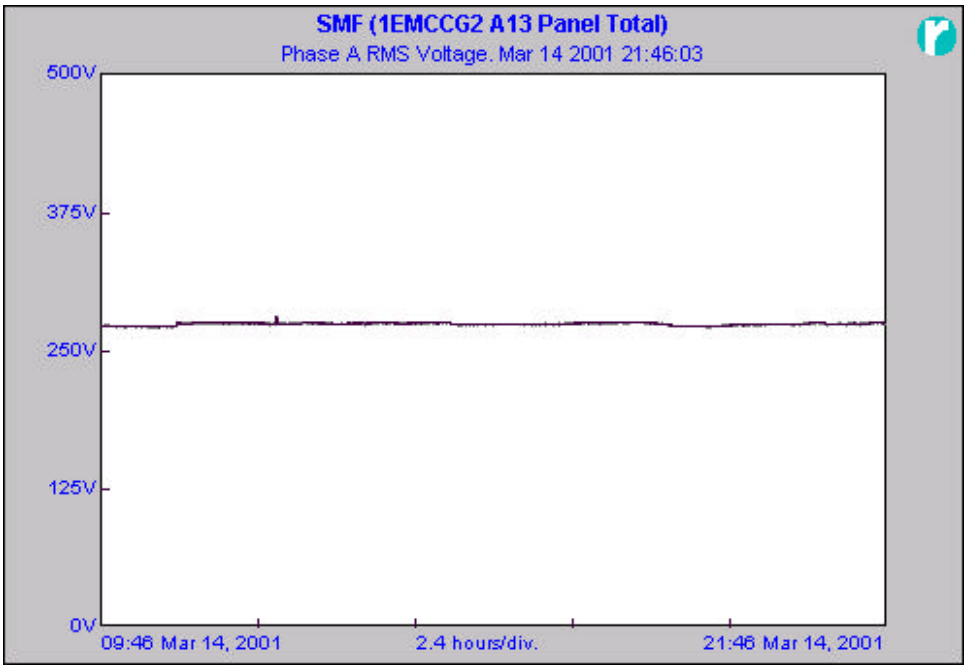
RMS. Voltages	Value	Date and Time
Phase A minimum	270.2V	Mar 14 2001 10:23:48
Phase A average	**274.8V**	
Phase A maximum	281.6V	Mar 14 2001 12:26:48
Phase B minimum	271.8V	Mar 14 2001 10:23:48
Phase B average	**277.3V**	
Phase B maximum	284.3V	Mar 14 2001 12:27:33
Phase C minimum	272.8V	Mar 14 2001 10:23:48
Phase C average	**276.6V**	
Phase C maximum	283.5V	Mar 14 2001 12:27:33
Neutral minimum	61.03mV	Mar 14 2001 10:24:03
Neutral average	**73.24mV**	
Neutral maximum	158.7mV	Mar 14 2001 15:00:18

RMS. Currents	Value	Date and Time
Phase A minimum	2.746A	Mar 14 2001 10:43:03
Phase A average	**15.20A**	
Phase A maximum	152.1A	Mar 14 2001 11:52:03
Phase B minimum	4.394A	Mar 14 2001 10:39:18
Phase B average	**19.32A**	
Phase B maximum	174.6A	Mar 14 2001 15:00:18
Phase C minimum	5.493A	Mar 14 2001 10:31:33
Phase C average	**17.97A**	
Phase C maximum	153.0A	Mar 14 2001 15:00:18
Neutral minimum	930.2mA	Mar 14 2001 09:46:03
Neutral average	**943.6mA**	
Neutral maximum	966.8mA	Mar 14 2001 11:23:18
Ground minimum	61.34mA	Mar 14 2001 09:47:03
Ground average	**62.88mA**	
Ground maximum	65.92mA	Mar 14 2001 09:52:48

Frequency	Value	Date and Time
Phase A minimum	59.96Hz	Mar 14 2001 15:42:18
Phase A average	**59.99Hz**	
Phase A maximum	60.04Hz	Mar 14 2001 14:00:03
Phase B minimum	59.96Hz	Mar 14 2001 15:42:18
Phase B average	**59.99Hz**	
Phase B maximum	60.04Hz	Mar 14 2001 14:00:03
Phase C minimum	59.96Hz	Mar 14 2001 15:42:18
Phase C average	**59.99Hz**	
Phase C maximum	60.04Hz	Mar 14 2001 14:00:03

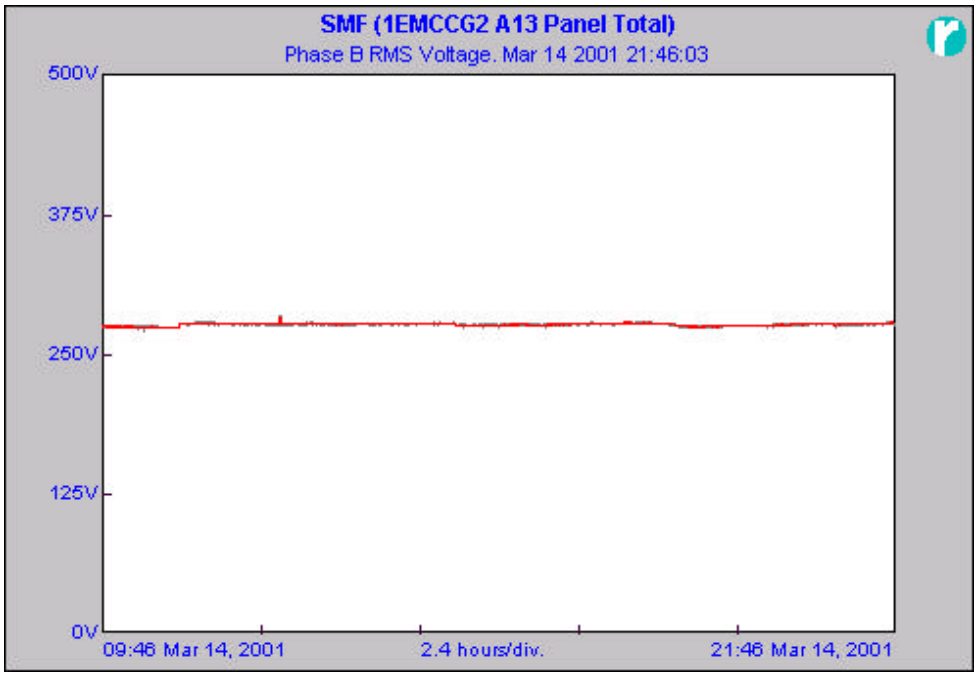
RMS Voltage Summaries for SMF MCC 1EMCCG2 A13 Panel Total.

Phase A Voltage Summary



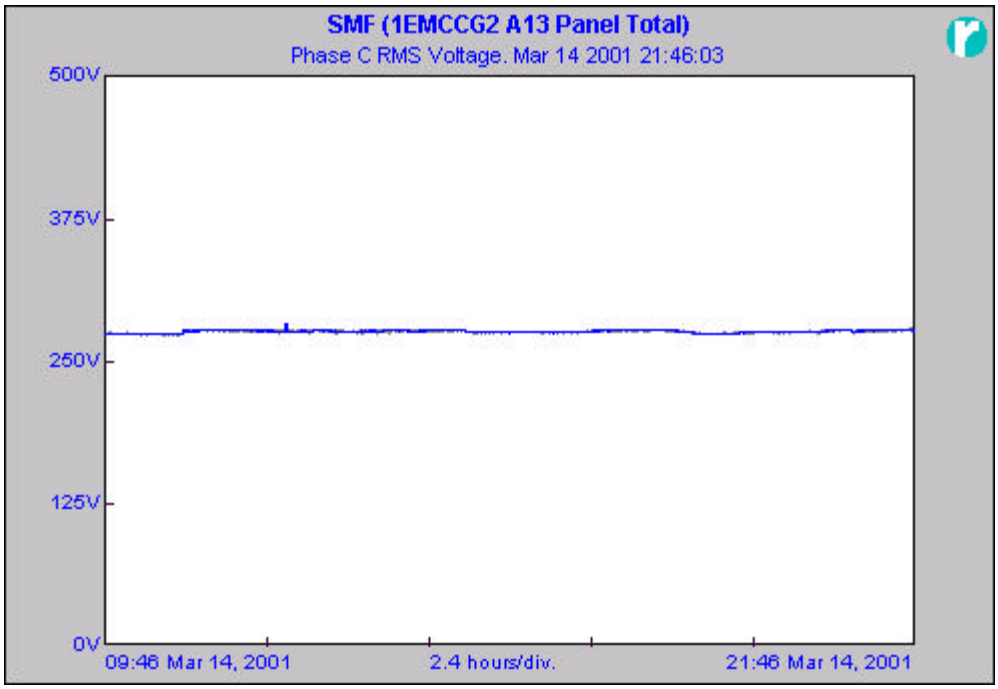
Min. 270.2V Mar 14 2001 10:23:48
Avg. 274.8V
Max. 281.6V Mar 14 2001 12:26:48

Phase B Voltage Summary



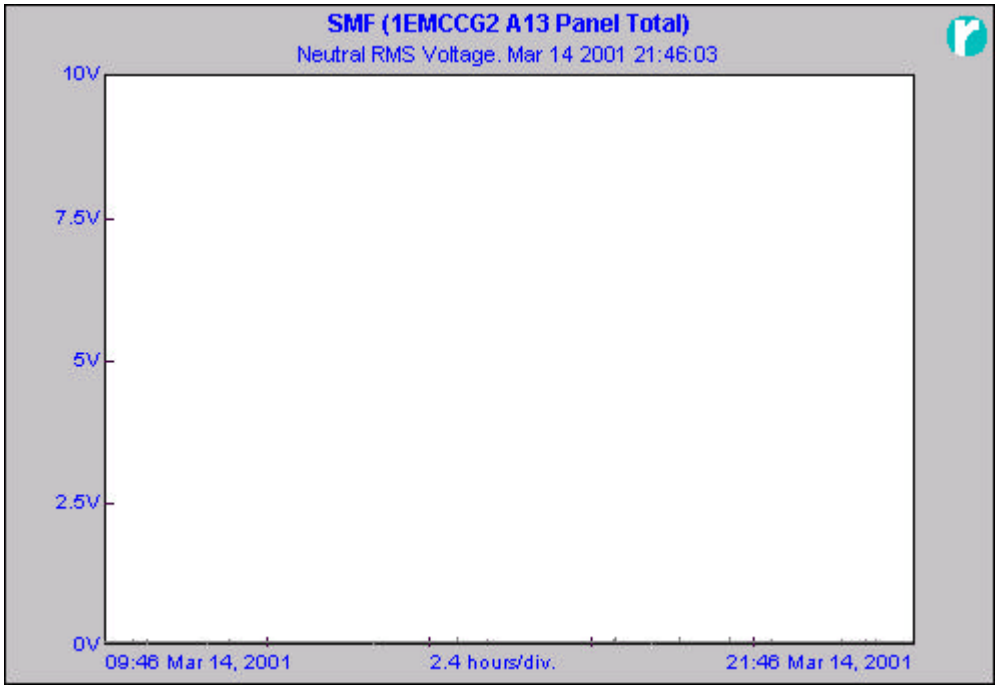
Min. 271.8V Mar 14 2001 10:23:48
Avg. 277.3V
Max. 284.3V Mar 14 2001 12:27:33

Phase C Voltage Summary



Min.	272.8V	Mar 14 2001 10:23:48
Avg.	**276.6V**	
Max.	283.5V	Mar 14 2001 12:27:33

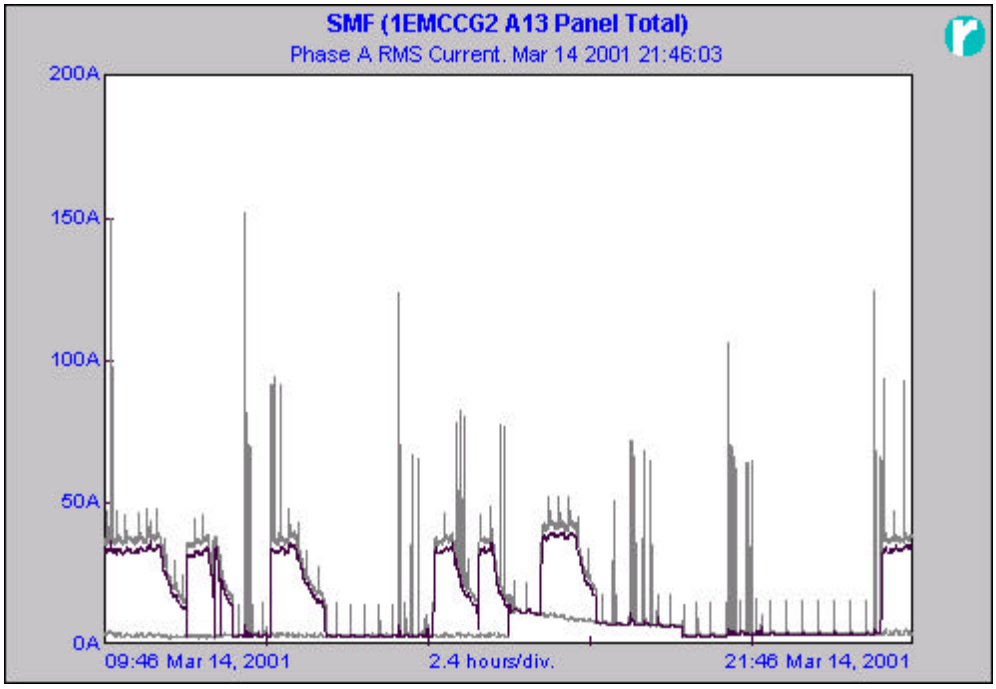
Neutral Voltage Summary



Min.	61.03mV	Mar 14 2001 10:24:03
Avg.	**73.24mV**	
Max.	158.7mV	Mar 14 2001 15:00:18

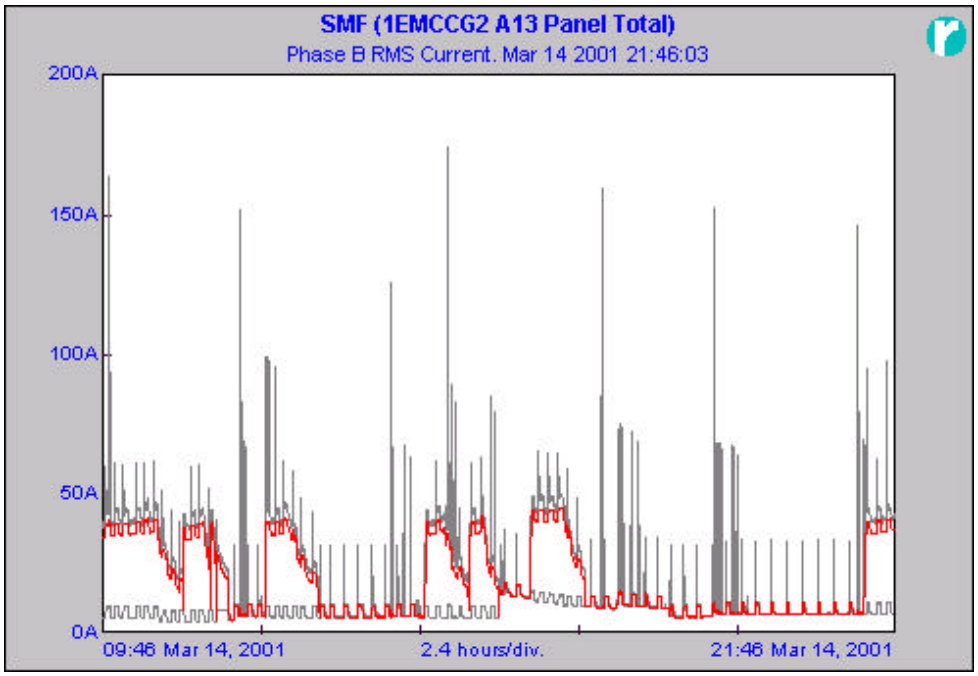
RMS. Current Summaries for SMF MCC 1EMCCG2 A13 Panel Total.

Phase A Current Summary



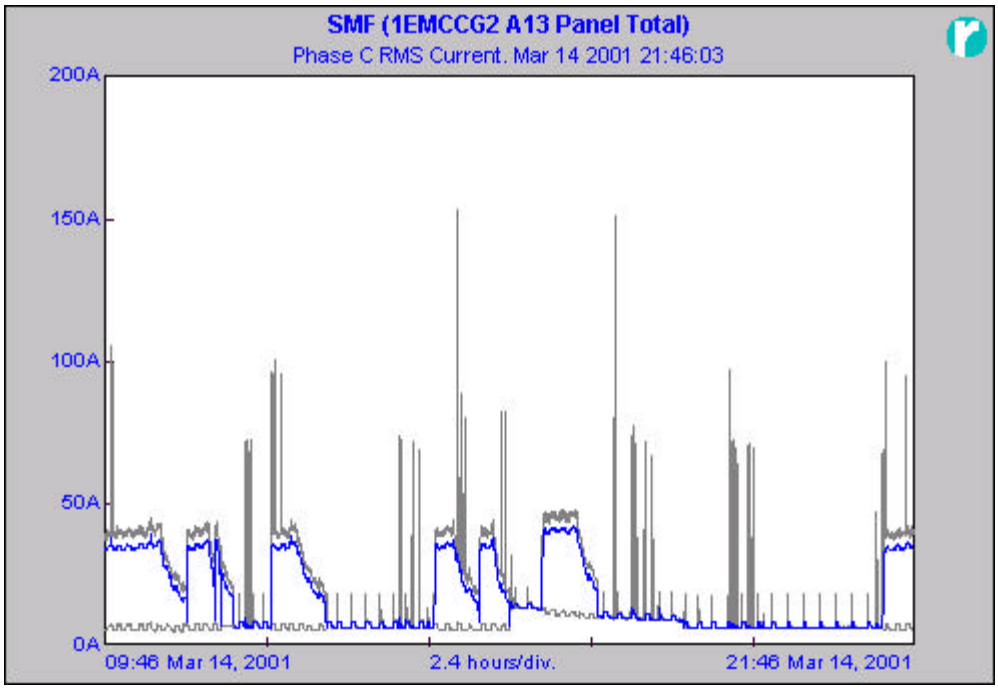
Min. 2.746A Mar 14 2001 10:43:03
Avg. 15.20A
Max. 152.1A Mar 14 2001 11:52:03

Phase B Current Summary



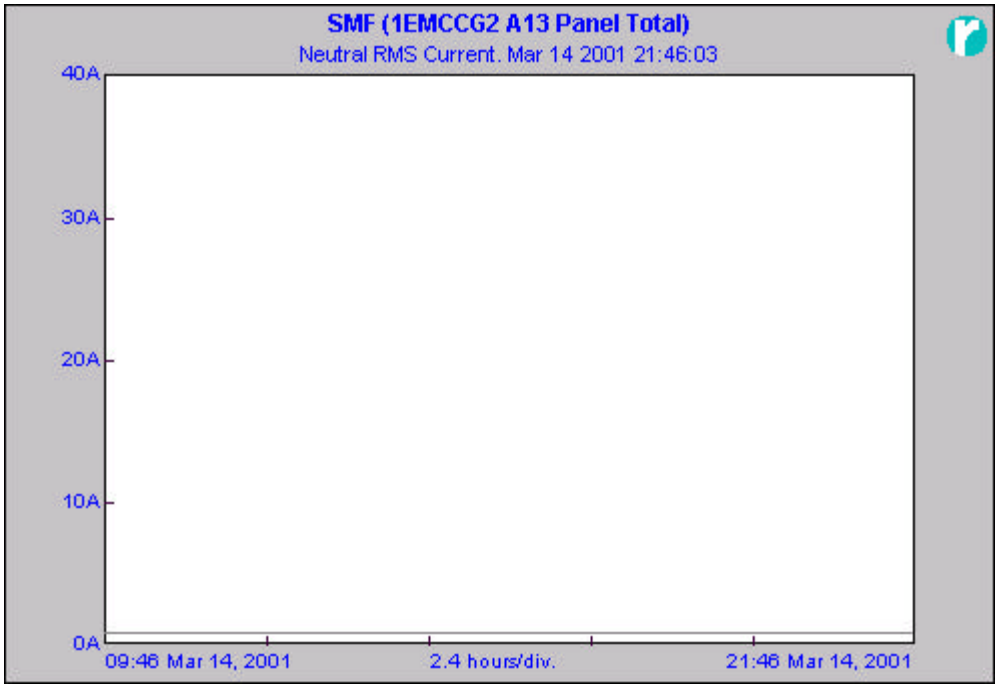
Min. 4.394A Mar 14 2001 10:39:18
Avg. 19.32A
Max. 174.6A Mar 14 2001 15:00:18

Phase C Current Summary



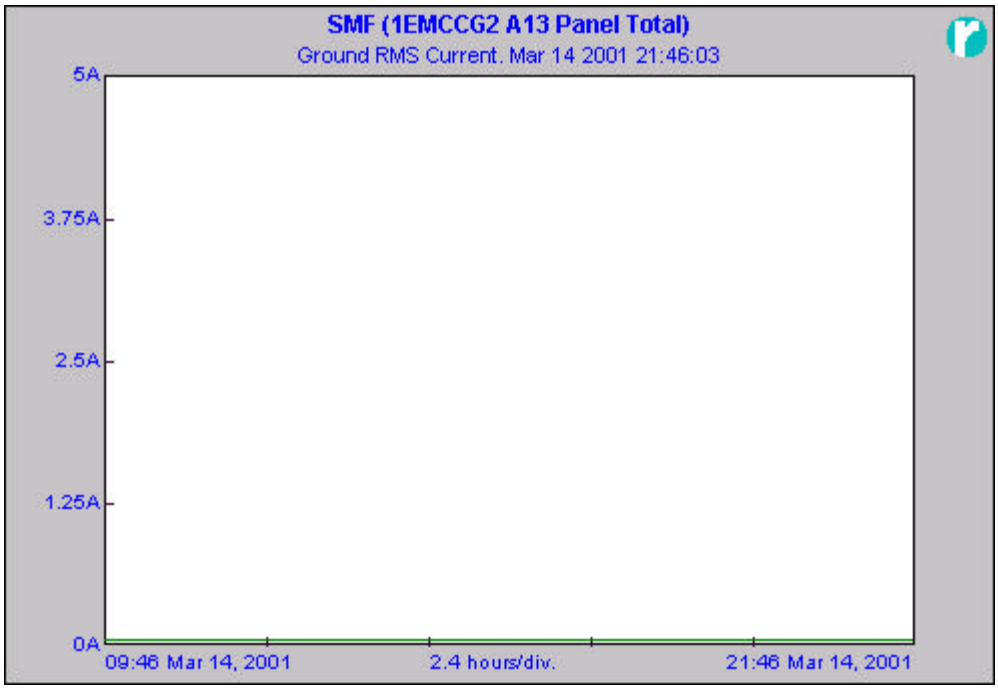
Min.	5.493A	Mar 14 2001 10:31:33
Avg.	**17.97A**	
Max.	153.0A	Mar 14 2001 15:00:18

Neutral Current Summary



Min.	930.2mA	Mar 14 2001 09:46:03
Avg.	**943.6mA**	
Max.	966.8mA	Mar 14 2001 11:23:18

Ground Current Summary



Min.	61.34mA	Mar 14 2001 09:47:03
Avg.	**62.88mA**	
Max.	65.92mA	Mar 14 2001 09:52:48

Voltage and Current Distortion Summaries

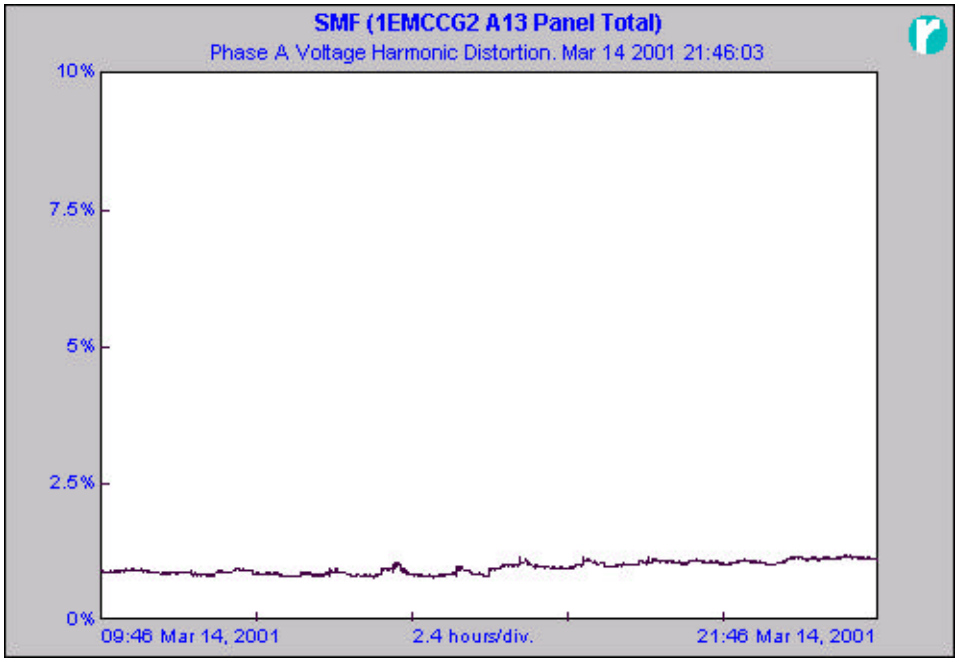
Voltage and Current harmonic distortion measurements for SMF MCC 1EMCCG2 A13 Panel Total from 03/14/01 09:46:03 through 03/14/01 21:46:03.

Voltage Distortion	Value	Date and Time
Phase A minimum	0.8%	Mar 14 2001 13:58:33
Phase A average	**0.979%**	
Phase A maximum	1.21%	Mar 14 2001 21:15:18
Phase B minimum	0.69%	Mar 14 2001 14:53:33
Phase B average	**0.844%**	
Phase B maximum	1.07%	Mar 14 2001 16:14:33
Phase C minimum	0.7%	Mar 14 2001 14:53:48
Phase C average	**0.868%**	
Phase C maximum	1.09%	Mar 14 2001 17:13:18

Current Distortion	Value	Date and Time
Phase A minimum	8.75%	Mar 14 2001 21:40:18
Phase A average	**42.41%**	
Phase A maximum	122.2%	Mar 14 2001 15:57:48
Phase B minimum	5.68%	Mar 14 2001 10:34:03
Phase B average	**20.86%**	
Phase B maximum	83.83%	Mar 14 2001 15:57:48
Phase C minimum	6.19%	Mar 14 2001 11:18:18
Phase C average	**22.38%**	
Phase C maximum	84.89%	Mar 14 2001 15:56:03

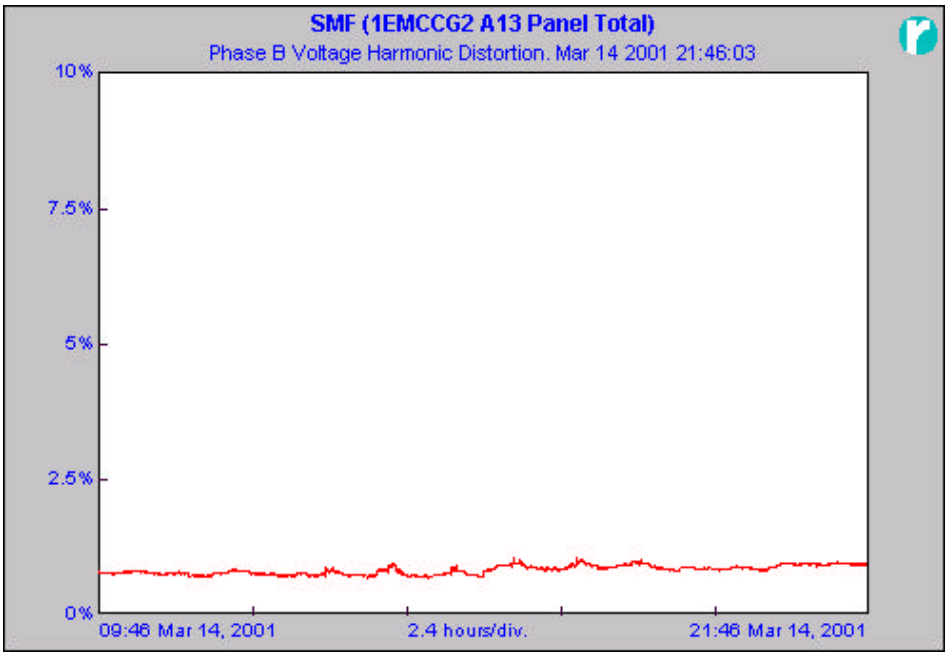
Voltage T.H.D. Summaries for SMF MCC 1EMCCG2 A13 Panel Total.

Phase A Voltage Distortion



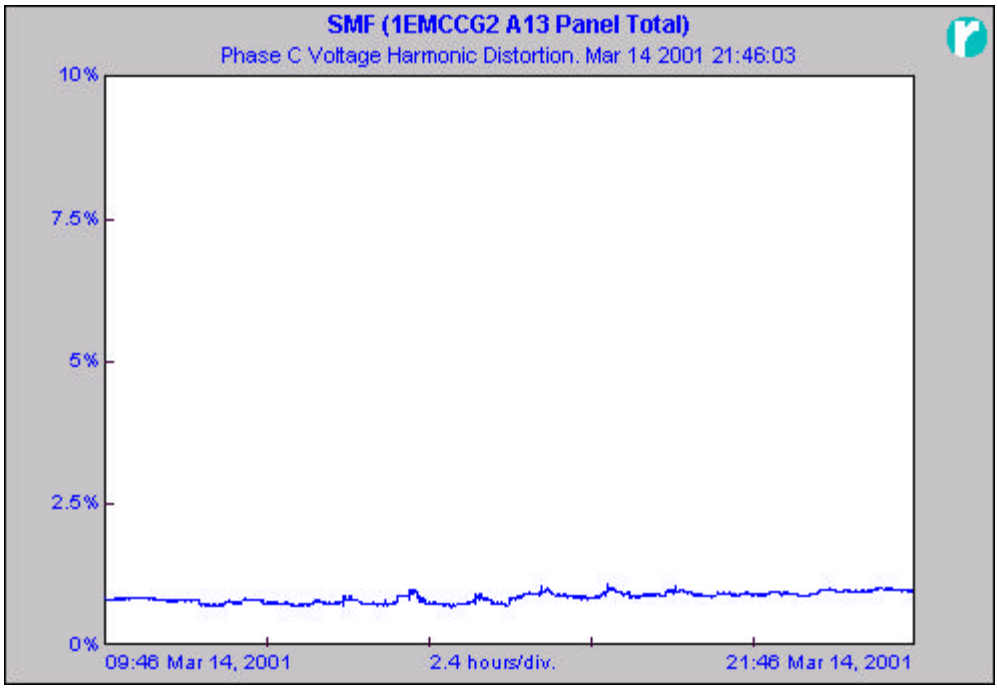
Min. 0.8% Mar 14 2001 13:58:33
Avg. 0.979%
Max. 1.21% Mar 14 2001 21:15:18

Phase B Voltage Distortion



Min. 0.69% Mar 14 2001 14:53:33
Avg. 0.844%
Max. 1.07% Mar 14 2001 16:14:33

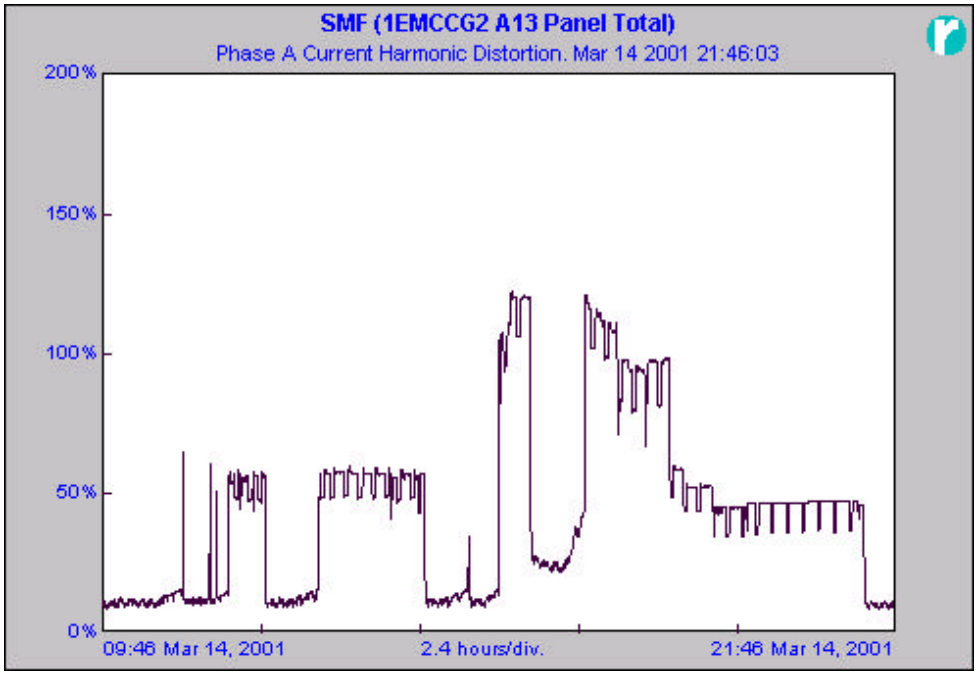
Phase C Voltage Distortion



Min.	0.7%	Mar 14 2001 14:53:48
Avg.	**0.868%**	
Max.	1.09%	Mar 14 2001 17:13:18

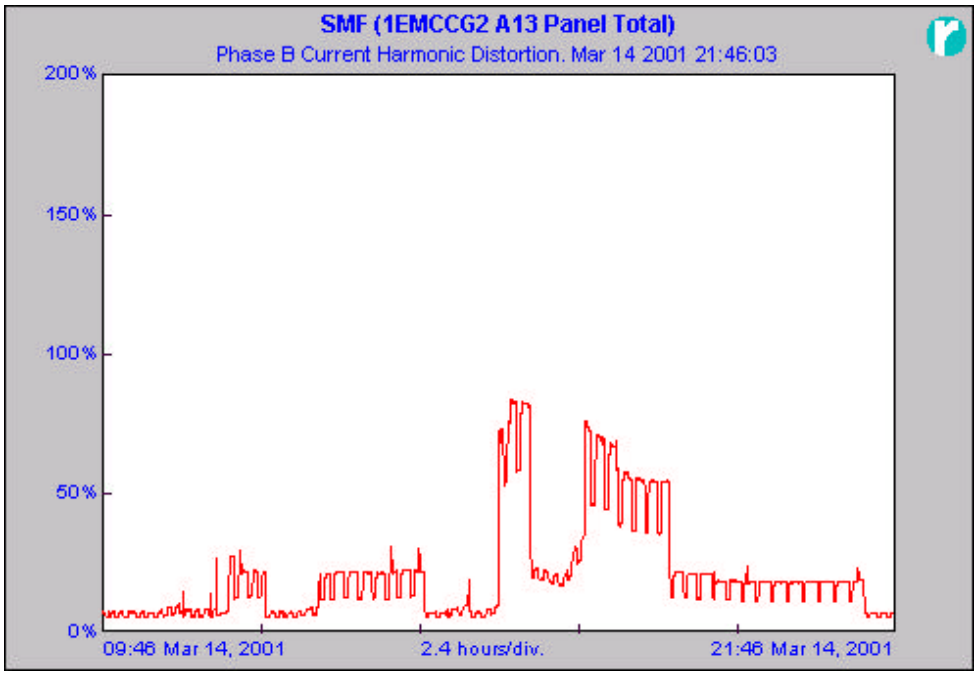
Current T.H.D. Summaries for SMF MCC 1EMCCG2 A13 Panel Total.

Phase A Current Distortion



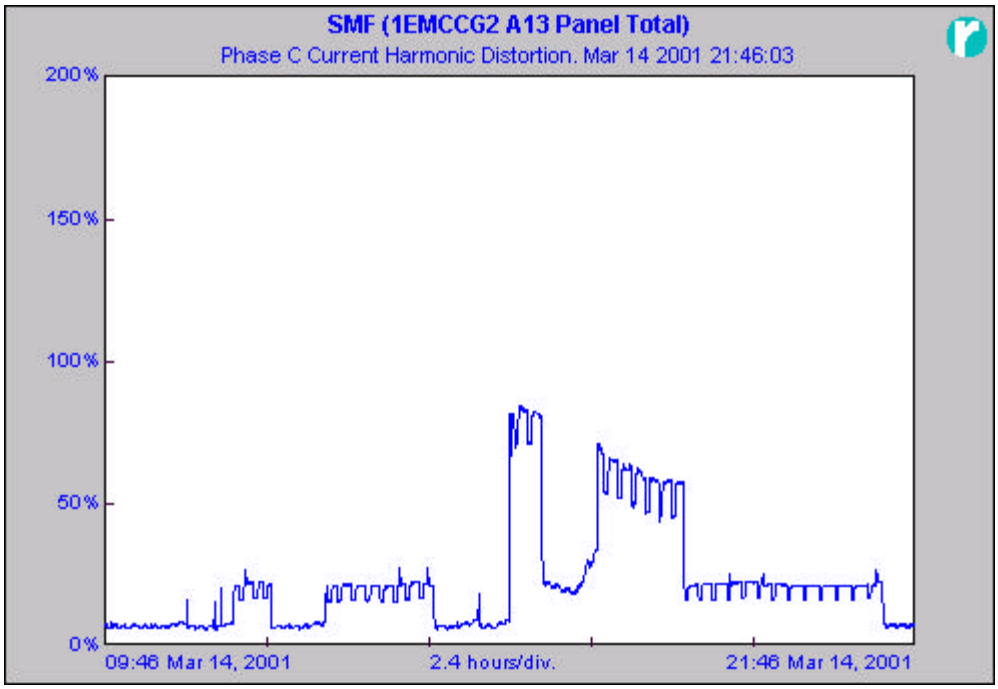
Min. 8.75% Mar 14 2001 21:40:18
Avg. 42.41%
Max. 122.2% Mar 14 2001 15:57:48

Phase B Current Distortion



Min. 5.68% Mar 14 2001 10:34:03
Avg. 20.86%
Max. 83.83% Mar 14 2001 15:57:48

Phase C Current Distortion



Min.	6.19%	Mar 14 2001 11:18:18
Avg.	**22.38%**	
Max.	84.89%	Mar 14 2001 15:56:03

Power Summaries

Power measurements for SMF MCC 1EMCCG2 A13 Panel Total from 03/14/01 09:46:03 through 03/14/01 21:46:03.

Imbalance	Value	Date and Time
Minimum Voltage Imbalance	0.42%	Mar 14 2001 13:08:03
Average Voltage Imbalance	**0.529%**	
Maximum Voltage Imbalance	0.67%	Mar 14 2001 19:22:18
Minimum Current Imbalance	2.47%	Mar 14 2001 09:55:18
Average Current Imbalance	**23.13%**	
Maximum Current Imbalance	57.52%	Mar 14 2001 10:59:18

VA Power	Value	Date and Time
Phase A minimum	773.5VA	Mar 14 2001 10:43:03
Phase A average	**4.228kVA**	
Phase A maximum	41.96kVA	Mar 14 2001 11:52:03
Phase B minimum	1.238kVA	Mar 14 2001 10:39:48
Phase B average	**5.410kVA**	
Phase B maximum	48.55kVA	Mar 14 2001 15:00:18
Phase C minimum	1.518kVA	Mar 14 2001 10:55:03
Phase C average	**5.022kVA**	
Phase C maximum	42.44kVA	Mar 14 2001 15:00:18
Total minimum	4.327kVA	Mar 14 2001 11:45:03
Total average	**14.66kVA**	
Total maximum	35.26kVA	Mar 14 2001 16:43:03

VARS Power	Value	Date and Time
Phase A minimum	-36.00kVAR	Mar 14 2001 11:52:03
Phase A average	**1.136kVAR**	
Phase A maximum	20.06kVAR	Mar 14 2001 14:08:48
Phase B minimum	-36.80kVAR	Mar 14 2001 17:19:18
Phase B average	**1.764kVAR**	
Phase B maximum	37.53kVAR	Mar 14 2001 11:52:03
Phase C minimum	-14.42kVAR	Mar 14 2001 14:08:48
Phase C average	**2.496kVAR**	
Phase C maximum	39.64kVAR	Mar 14 2001 17:19:18
Total minimum	2.895kVAR	Mar 14 2001 18:48:18
Total average	**5.397kVAR**	
Total maximum	9.849kVAR	Mar 14 2001 16:15:48

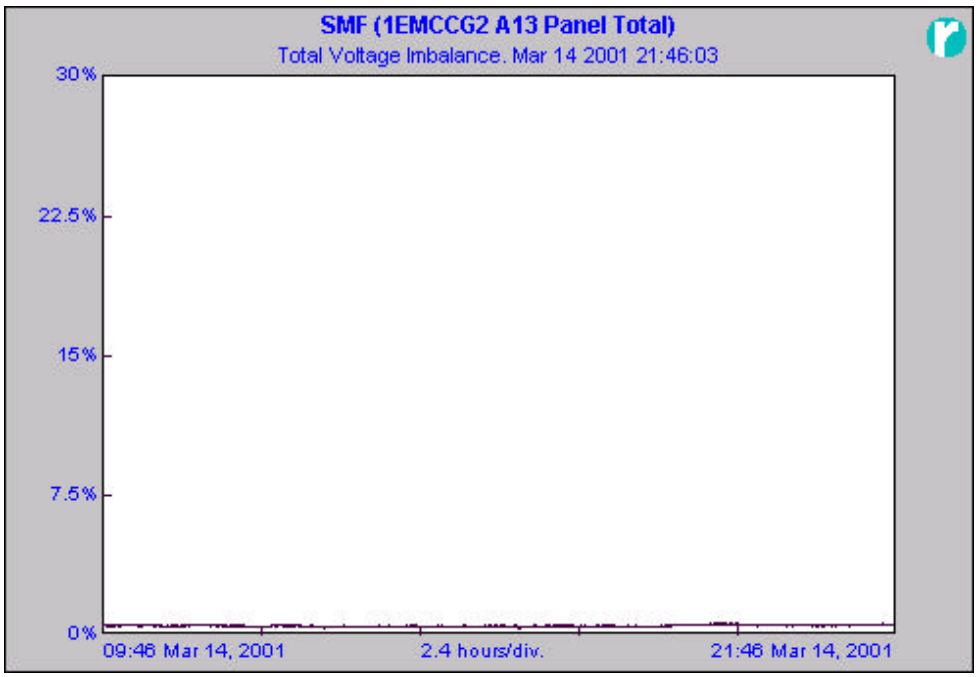
Watts Power	Value	Date and Time
Phase A minimum	-430.4W	Mar 14 2001 14:19:48
Phase A average	**3.846kW**	
Phase A maximum	25.18kW	Mar 14 2001 09:52:18
Phase B minimum	11.11W	Mar 14 2001 21:19:18
Phase B average	**5.035kW**	
Phase B maximum	33.05kW	Mar 14 2001 15:00:18
Phase C minimum	-1.024kW	Mar 14 2001 09:57:33
Phase C average	**4.036kW**	
Phase C maximum	24.39kW	Mar 14 2001 09:52:18
Total minimum	2.136kW	Mar 14 2001 11:45:03
Total average	**12.91kW**	
Total maximum	33.68kW	Mar 14 2001 16:43:03

Demand Power	Value	Date and Time
Phase A minimum	589.5W	Mar 14 2001 11:46:03
Phase A average	**3.846kW**	
Phase A maximum	10.22kW	Mar 14 2001 16:26:03
Phase B minimum	1.689kW	Mar 14 2001 18:31:03
Phase B average	**5.033kW**	
Phase B maximum	11.61kW	Mar 14 2001 16:36:03
Phase C minimum	811.3W	Mar 14 2001 18:31:03
Phase C average	**4.035kW**	
Phase C maximum	10.70kW	Mar 14 2001 16:36:03
Total minimum	3.155kW	Mar 14 2001 18:31:03
Total average	**12.91kW**	
Total maximum	32.53kW	Mar 14 2001 16:36:03

Power Factor	Value	Date and Time
Phase A minimum	0.002 Lead	Mar 14 2001 14:43:48
Phase A average	**0.846 Lag**	
Phase A maximum	0.000 Lag	Mar 14 2001 11:19:48
Phase B minimum	0.364 Lead	Mar 14 2001 11:02:33
Phase B average	**0.888 Lag**	
Phase B maximum	0.003 Lag	Mar 14 2001 21:19:18
Phase C minimum	0.486 Lead	Mar 14 2001 14:08:48
Phase C average	**0.646 Lag**	
Phase C maximum	0.000 Lag	Mar 14 2001 10:33:48
Total minimum	0.963	Mar 14 2001 10:34:48
Total average	**0.783**	
Total maximum	0.490	Mar 14 2001 11:45:48

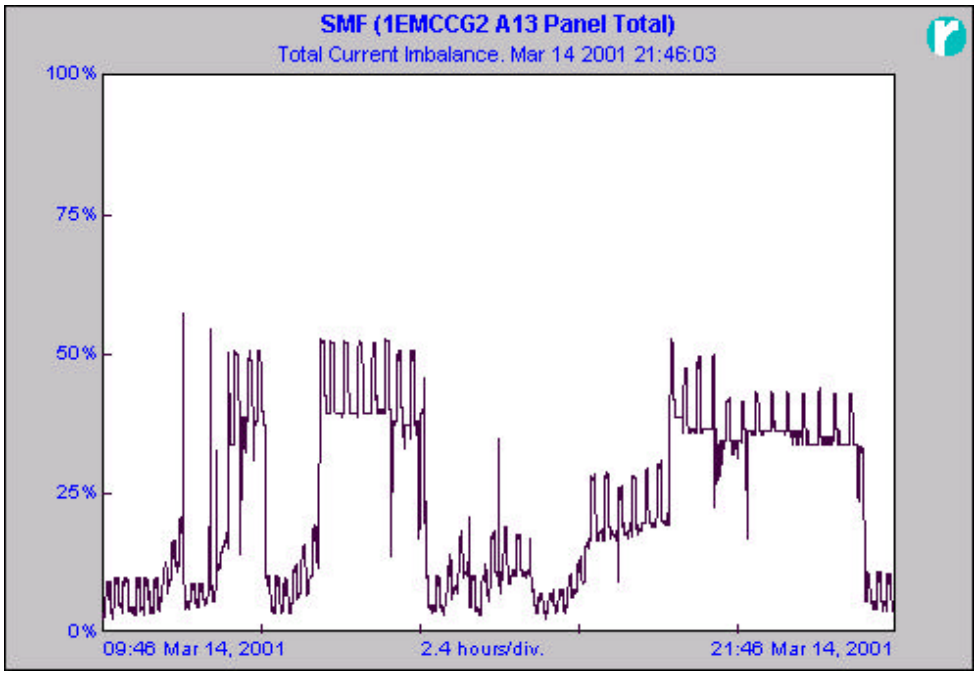
Voltage and Current Imbalance Summaries for SMF MCC 1EMCCG2 A13 Panel Total

Voltage Imbalance



Minimum Voltage Imbalance	0.42%	Mar 14 2001 13:08:03
Average Voltage Imbalance	**0.529%**	
Maximum Voltage Imbalance	0.67%	Mar 14 2001 19:22:18

Current Imbalance

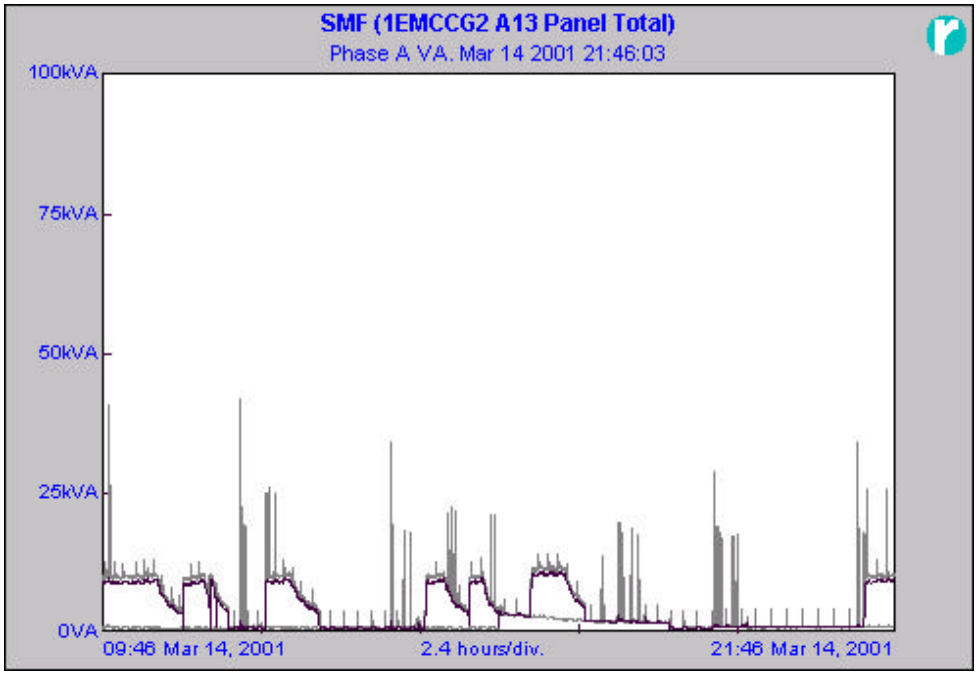


Minimum Current Imbalance	2.47%	Mar 14 2001 09:55:18

Average Current Imbalance	**23.13%**	
Maximum Current Imbalance	57.52%	Mar 14 2001 10:59:18

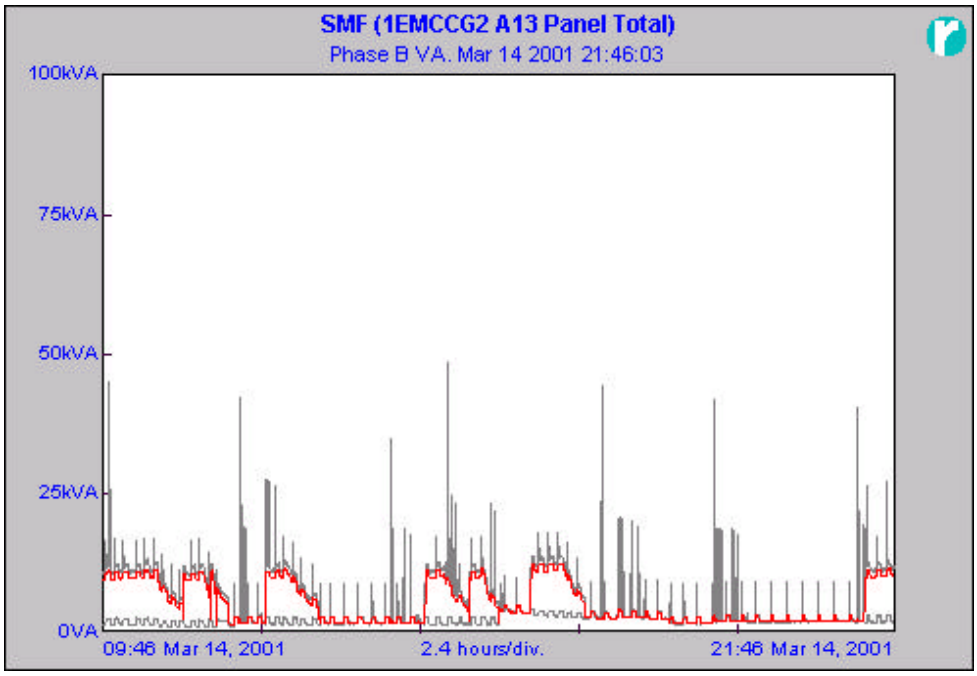
VA Power Summaries for SMF MCC 1EMCCG2 A13 Panel Total.

Phase A VA Summary



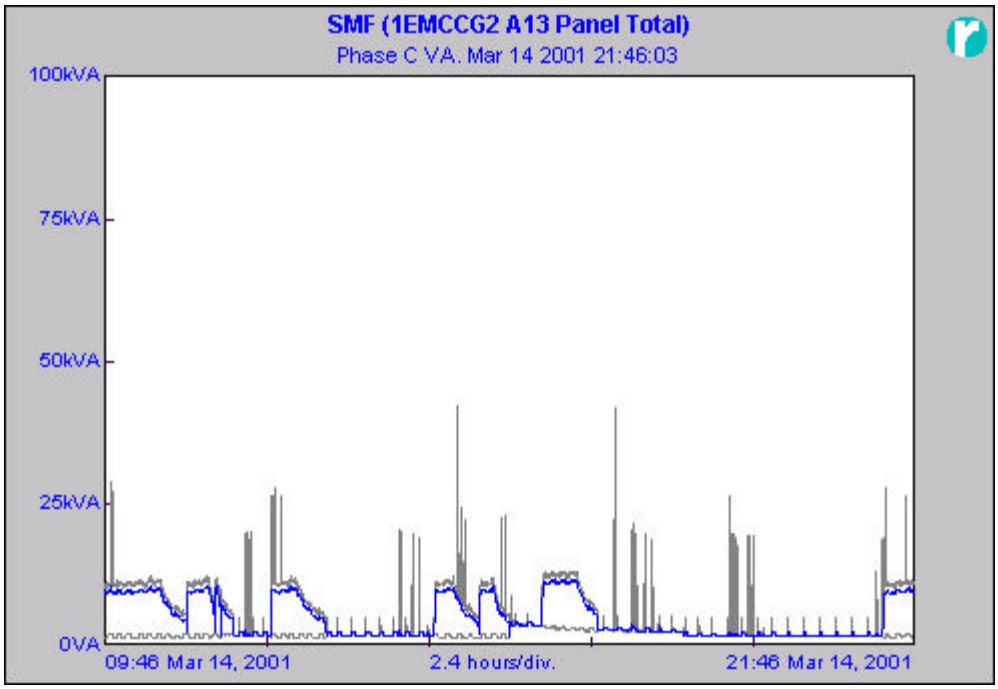
Min. 773.5VA Mar 14 2001 10:43:03
Avg. 4.228kVA
Max. 41.96kVA Mar 14 2001 11:52:03

Phase B VA Summary



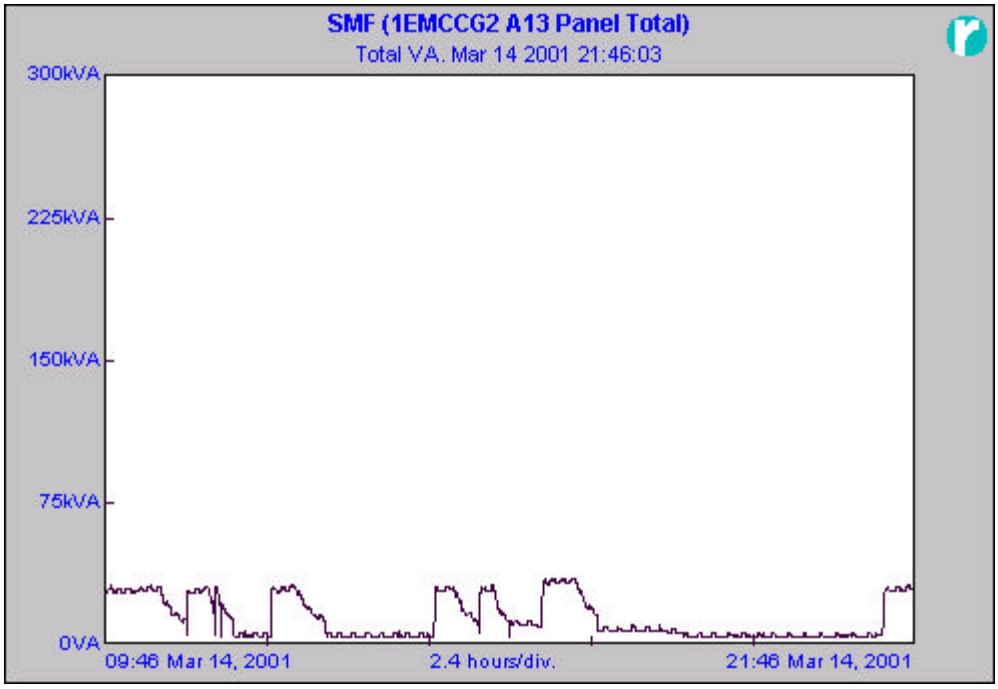
Min. 1.238kVA Mar 14 2001 10:39:48
Avg. 5.410kVA
Max. 48.55kVA Mar 14 2001 15:00:18

Phase C VA Summary



Min. 1.518kVA Mar 14 2001 10:55:03
Avg. 5.022kVA
Max. 42.44kVA Mar 14 2001 15:00:18

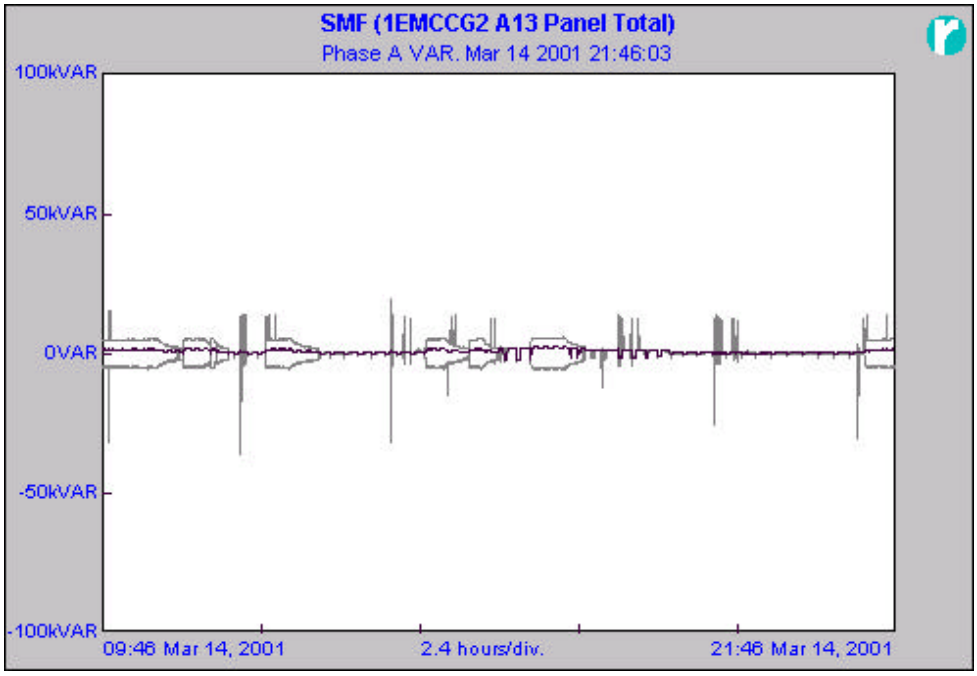
Total VA Summary



Min. 4.327kVA Mar 14 2001 11:45:03
Avg. 14.66kVA
Max. 35.26kVA Mar 14 2001 16:43:03

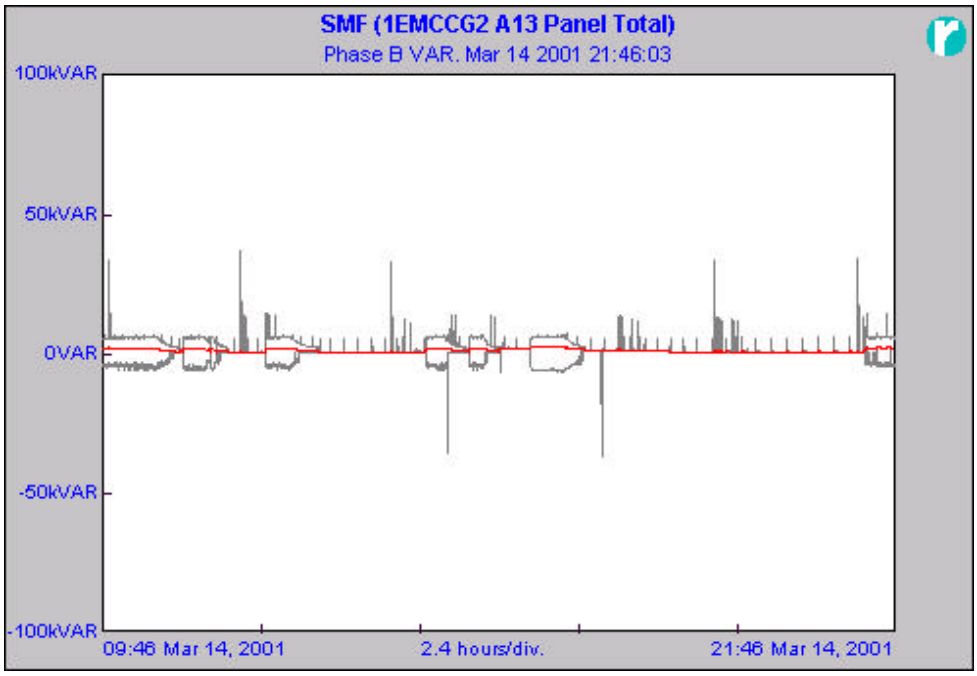
VARS Power Summaries for SMF MCC 1EMCCG2 A13 Panel Total.

Phase A VARS Summary



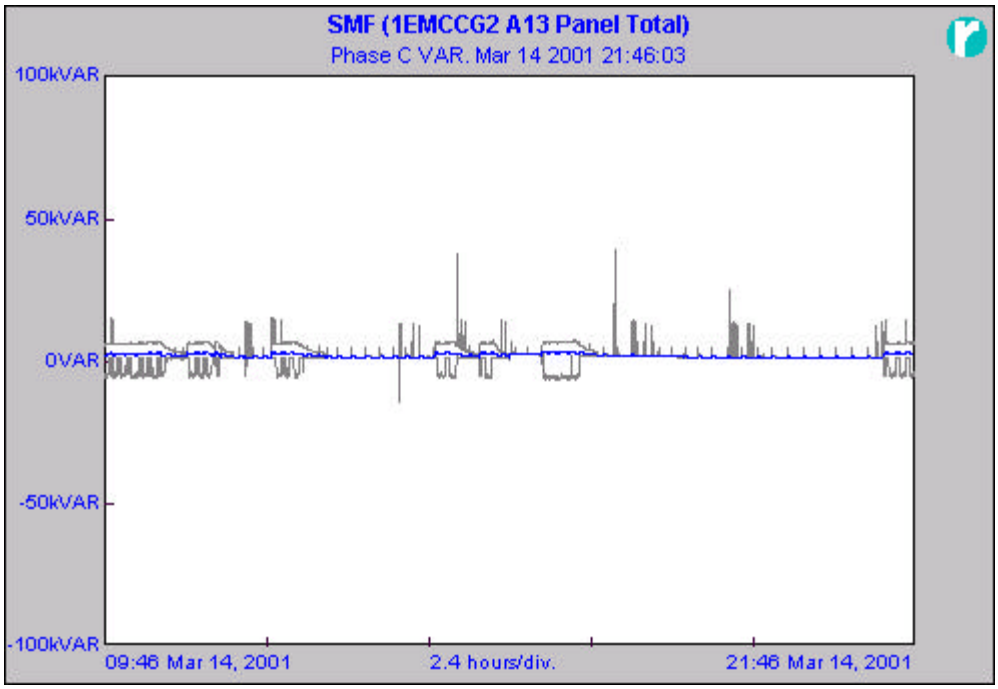
Min. -36.00kVAR Mar 14 2001 11:52:03
Avg. 1.136kVAR
Max. 20.06kVAR Mar 14 2001 14:08:48

Phase B VARS Summary



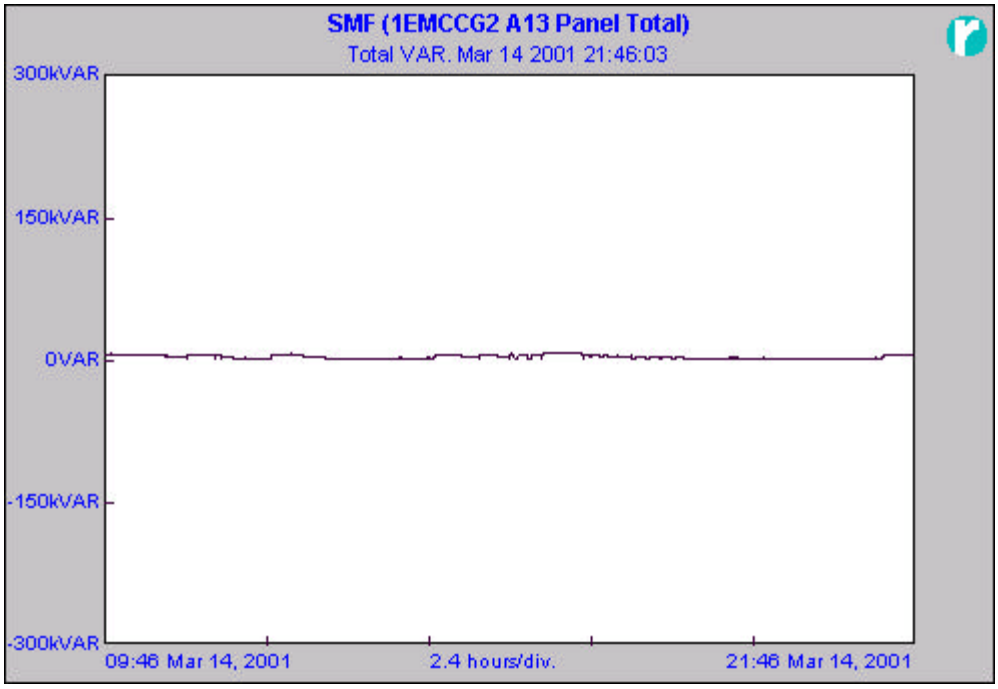
Min. -36.80kVAR Mar 14 2001 17:19:18
Avg. 1.764kVAR
Max. 37.53kVAR Mar 14 2001 11:52:03

Phase C VARS Summary



Min. -14.42kVAR Mar 14 2001 14:08:48
Avg. 2.496kVAR
Max. 39.64kVAR Mar 14 2001 17:19:18

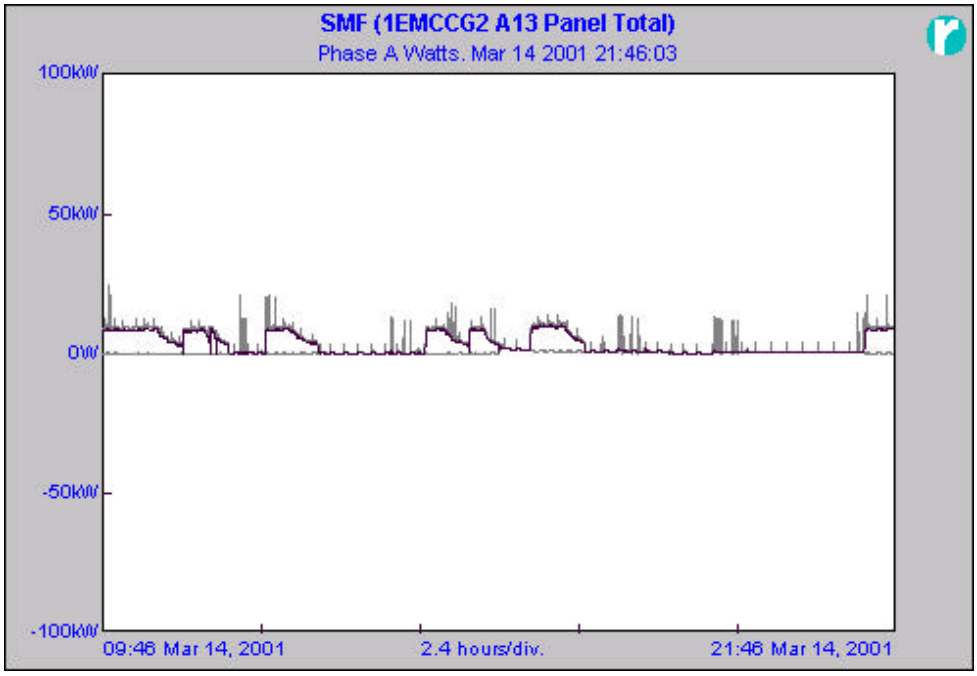
Total VARS Summary



Min. 2.895kVAR Mar 14 2001 18:48:18
Avg. 5.397kVAR
Max. 9.849kVAR Mar 14 2001 16:15:48

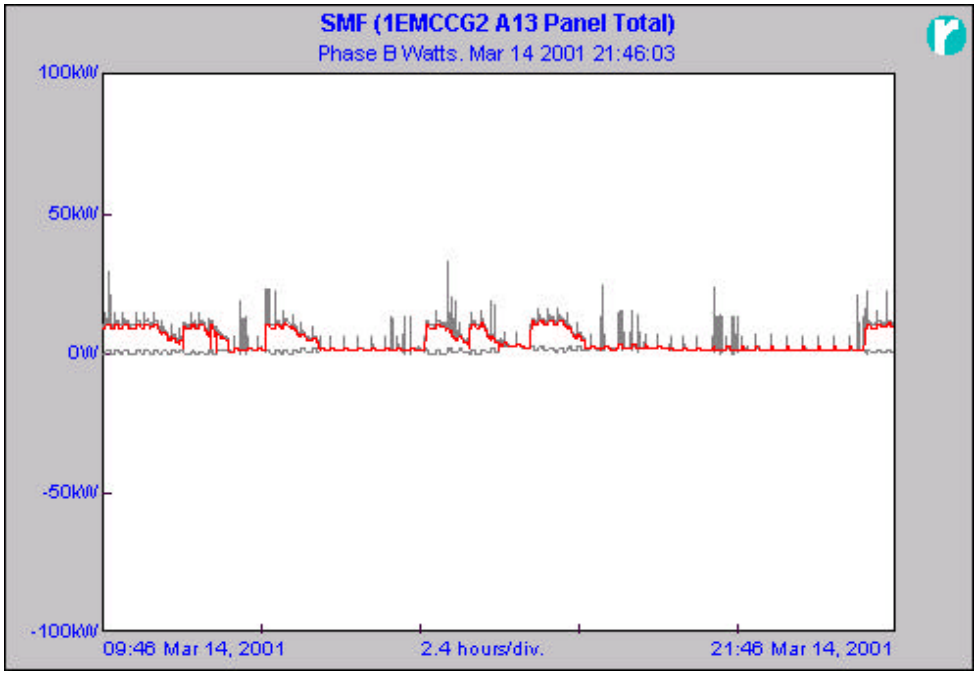
WATTS Power Summaries for SMF MCC 1EMCCG2 A13 Panel Total.

Phase A Watts Summary



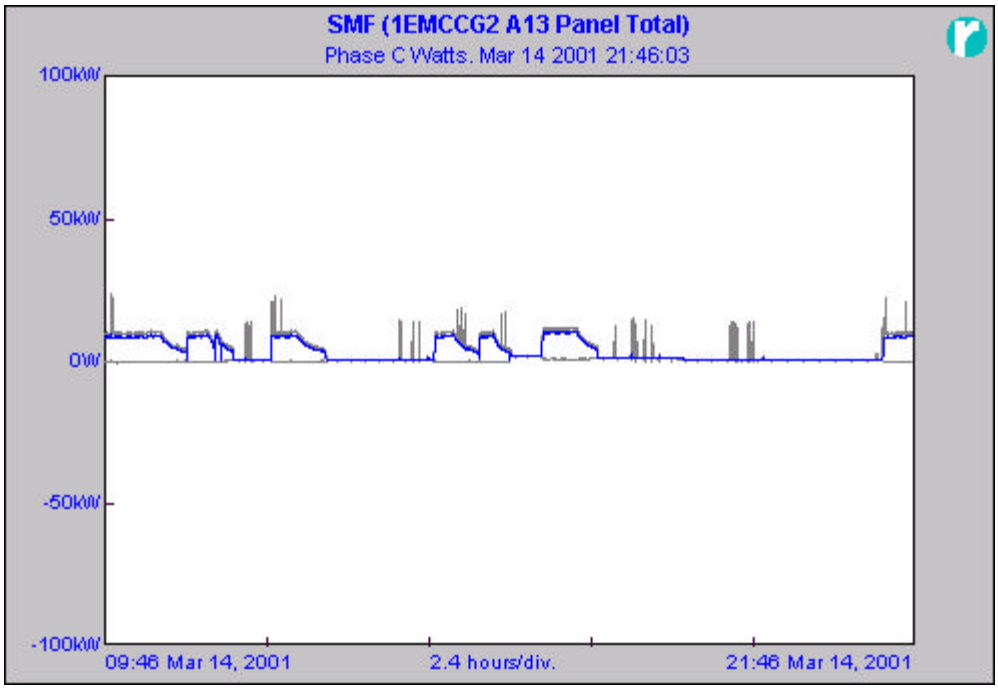
Min. -430.4W Mar 14 2001 14:19:48
Avg. 3.846kW
Max. 25.18kW Mar 14 2001 09:52:18

Phase B Watts Summary



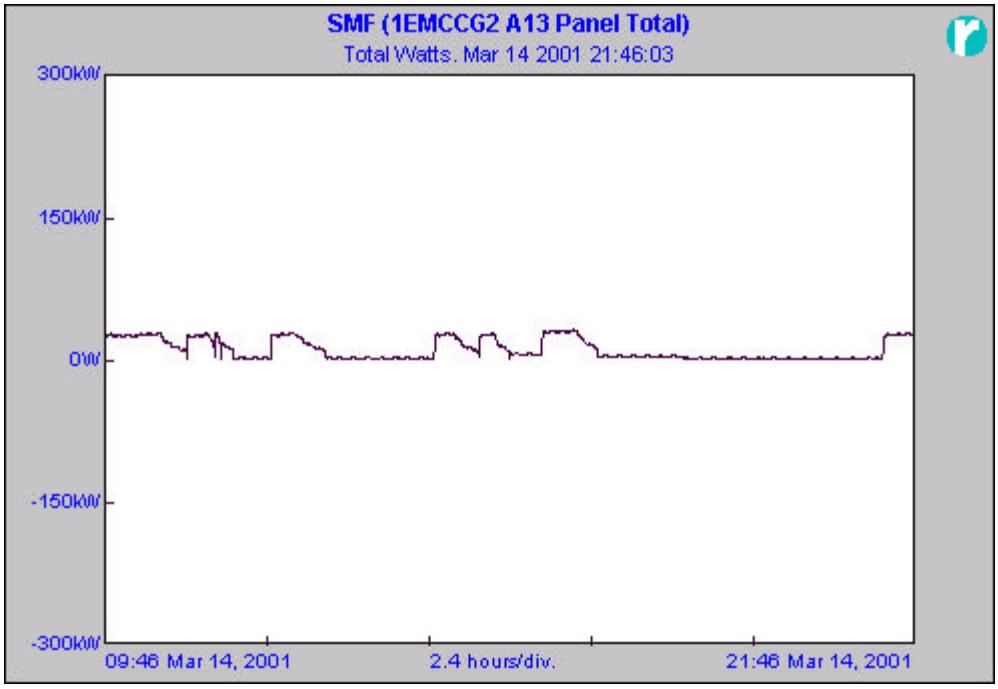
Min. 11.11W Mar 14 2001 21:19:18
Avg. 5.035kW
Max. 33.05kW Mar 14 2001 15:00:18

Phase C Watts Summary



Min. -1.024kW Mar 14 2001 09:57:33
Avg. 4.036kW
Max. 24.39kW Mar 14 2001 09:52:18

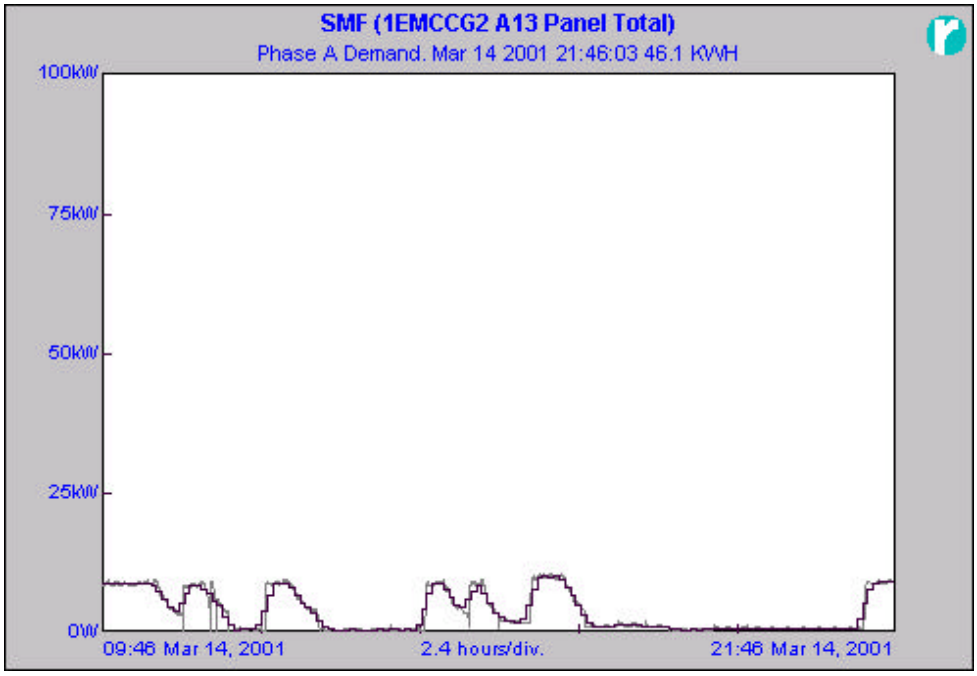
Total Watts Summary



Min. 2.136kW Mar 14 2001 11:45:03
Avg. 12.91kW
Max. 33.68kW Mar 14 2001 16:43:03

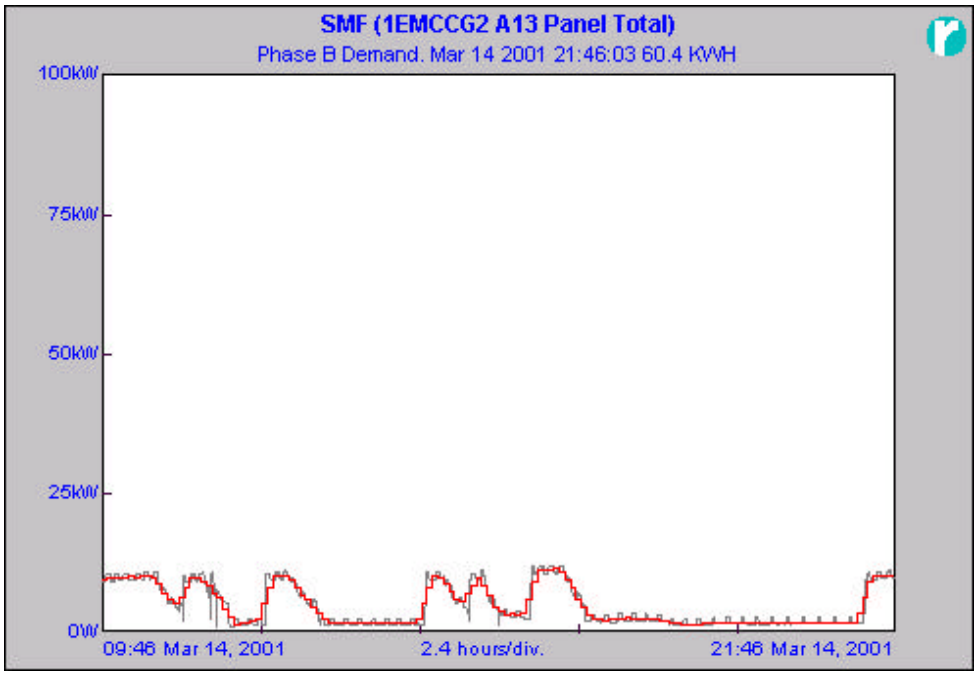
Demand Power Summaries for SMF MCC 1EMCCG2 A13 Panel Total.

Phase A Demand Summary



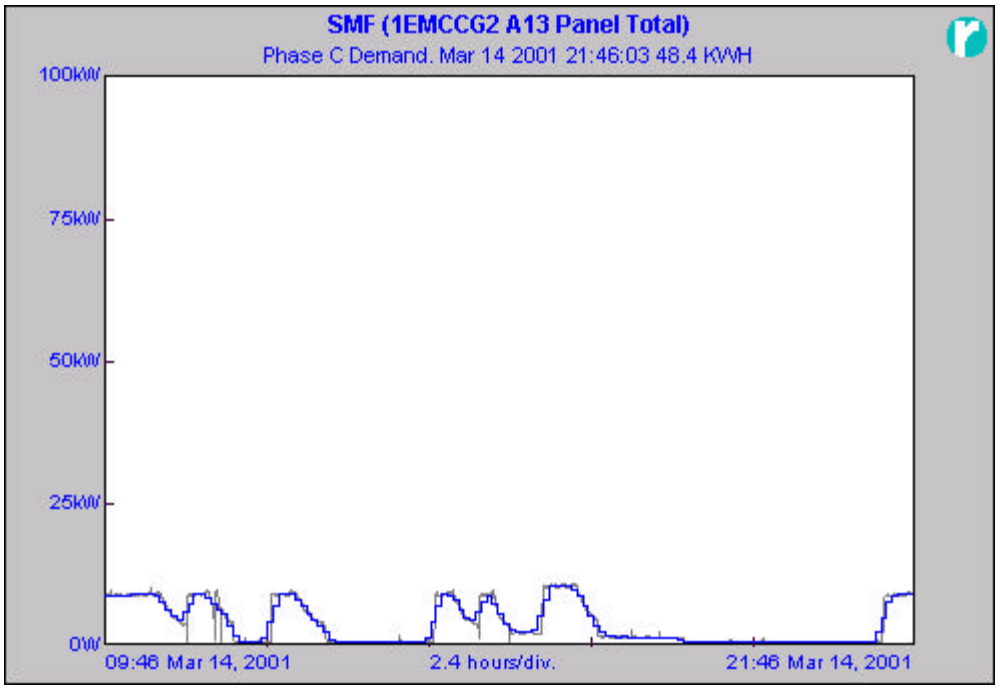
Min. 589.5W Mar 14 2001 11:46:03
Avg. 3.846kW
Max. 10.22kW Mar 14 2001 16:26:03

Phase B Demand Summary



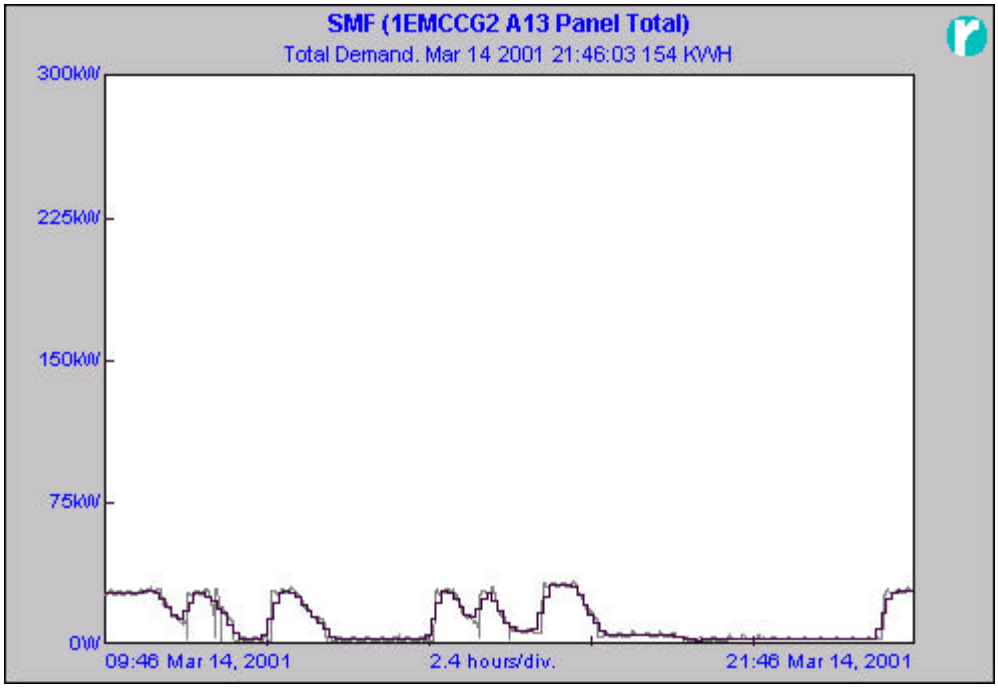
Min. 1.689kW Mar 14 2001 18:31:03
Avg. 5.033kW
Max. 11.61kW Mar 14 2001 16:36:03

Phase C Demand Summary



Min.	811.3W	Mar 14 2001 18:31:03
Avg.	**4.035kW**	
Max.	10.70kW	Mar 14 2001 16:36:03

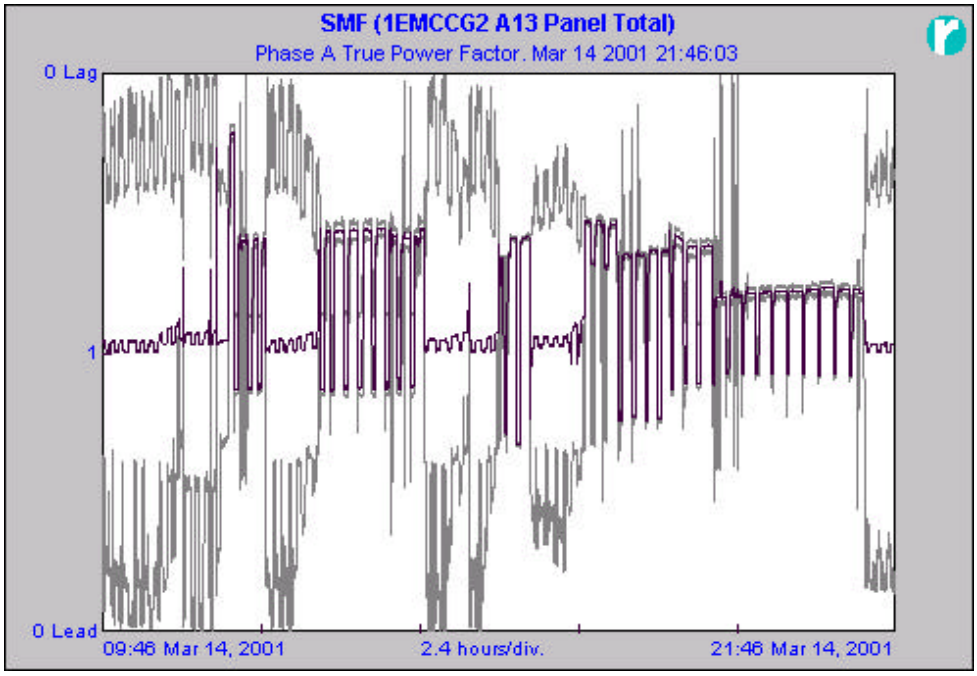
Total Demand Summary



Min.	3.155kW	Mar 14 2001 18:31:03
Avg.	**12.91kW**	
Max.	32.53kW	Mar 14 2001 16:36:03

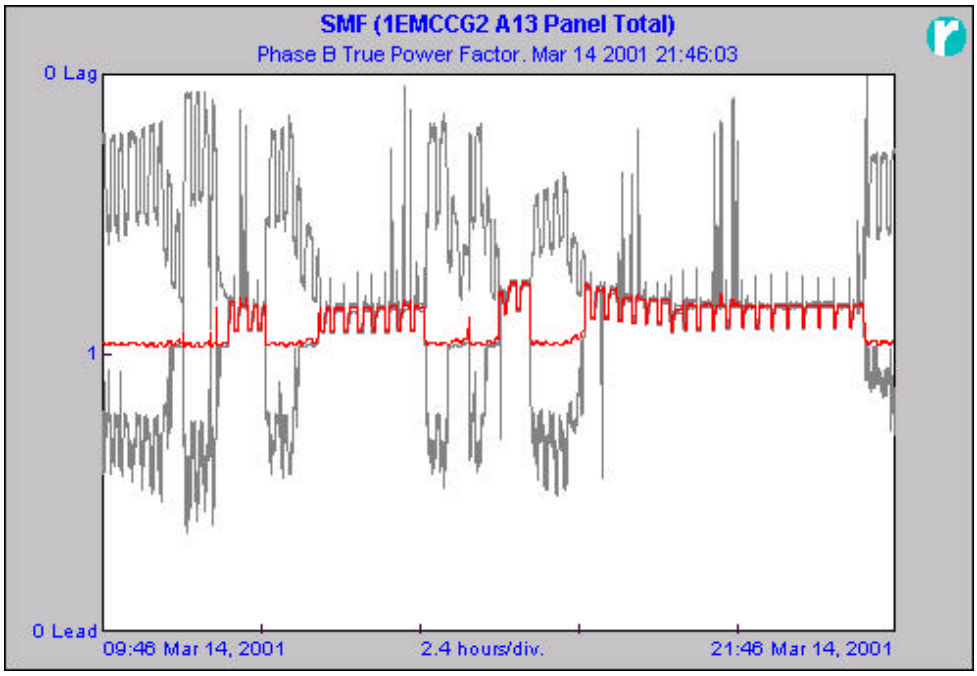
Power Factor Summaries for SMF MCC 1EMCCG2 A13 Panel Total.

Phase A Power Factor Summary



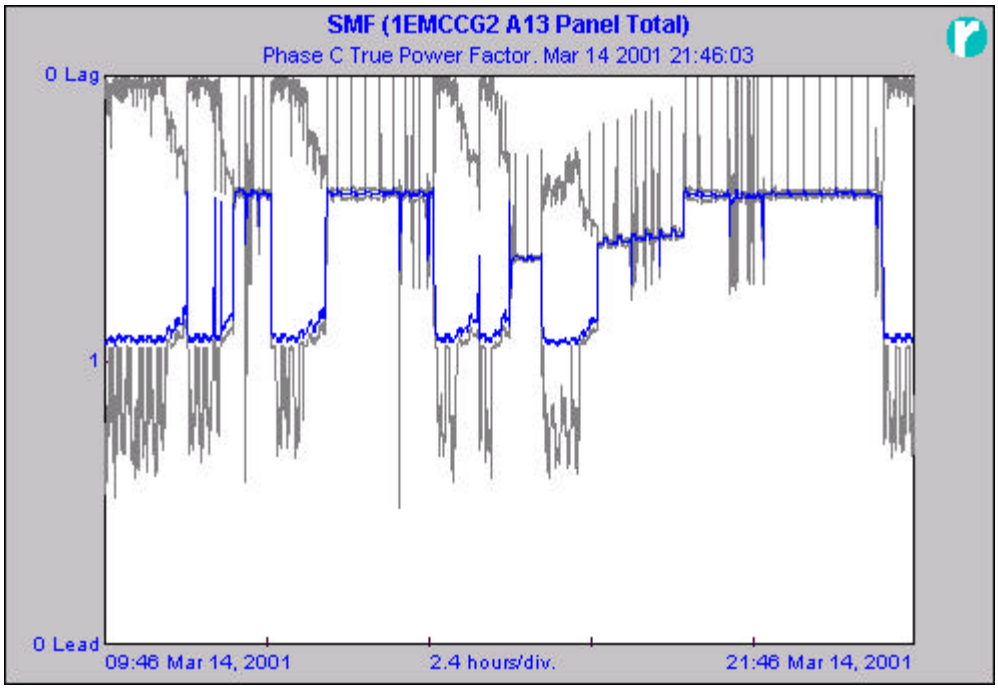
Min. 0.002 Lead Mar 14 2001 14:43:48
Avg. 0.846 Lag
Max. 0.000 Lag Mar 14 2001 11:19:48

Phase B Power Factor Summary



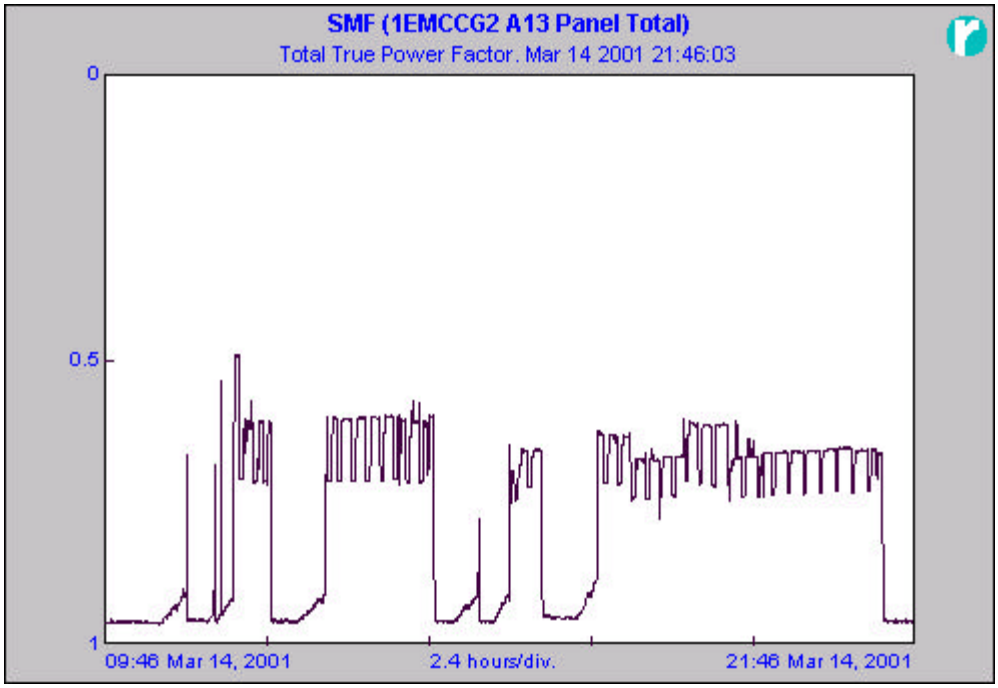
Min. 0.364 Lead Mar 14 2001 11:02:33
Avg. 0.888 Lag
Max. 0.003 Lag Mar 14 2001 21:19:18

Phase C Power Factor Summary



Min. 0.486 Lead Mar 14 2001 14:08:48
Avg. 0.646 Lag
Max. 0.000 Lag Mar 14 2001 10:33:48

Total Power Factor Summary



Min. 0.963 Mar 14 2001 10:34:48
Avg. 0.783
Max. 0.490 Mar 14 2001 11:45:48